Scientific Excellence • Resource Protection & Conservation • Benefits for Canadians
Excellence scientifique • Protection et conservation des ressources • Bénéfices aux Canadiens

MULTI-YEAR RESEARCH PLAN

Regional Science Branch - Quebec Region

1992/1996

MAURICE LAMONTAGNE INSTITUTE • MARINE SCIENCES RESEARCH CENTRE

Canada

MULTI-YEAR RESEARCH PLAN

1992 - 1996

REGIONAL SCIENCE BRANCH
QUEBEC REGION

DEPARTMENT OF FISHERIES AND OCEANS
MAURICE LAMONTAGNE INSTITUTE
P.O. BOX 1000, MONT-JOLI, QUEBEC
CANADA G5H 3Z4

1992

93-00899/

Published by:

Regional Science Branch
Department of Fisheries and Oceans
Quebec Region
Maurice Lamontagne Institute
P.O. Box 1000
Mont-Joli, Quebec
G5H 3Z4

© Minister of Supply and
Services Canada 1992

Cat. No. Fs 1-55/1992 E
ISBN 0-662-19301-6

Disponible en français

EXECUTIVE SUMMARY

This plan outlines the research directions proposed by the Regional Science Branch - Quebec Region (RSBQ) for 1992-1996 in biology, physics, chemistry and hydrography. These proposals ensue from consultations with clients, particularly the fishing industry, and with partners of the Branch, which include federal and provincial government departments as well as universities. The Symposium on the Gulf of St. Lawrence and the Workshop on the Hudson Strait, held in 1989, are particularly noteworthy because they made it possible to pinpoint the main scientific issues concerning the two major geographic areas that fall under the purview of the Department of Fisheries and Oceans (DFO), Quebec Region.

The long-term priorities are based on the assumption that a budget comparable to that of 1991-92 will be maintained, that is, close to $20 M, of which there are about 220 person-years. These priorities are consistent with the general research and survey mission of the Maurice Lamontagne Institute (MLI), which has been in charge of scientific activities in the Quebec Region since fall 1986. The MLI is part of the DFO's network of eleven research centres and laboratories, each of which is responsible for a specific area of Canada. Research in the Gulf is conducted in co-operation with the Moncton laboratory, whereas studies concerning the Eastern Arctic are carried out jointly with the Freshwater Institute in Winnipeg.

The geographic area covered by the Branch includes the St. Lawrence Estuary and the Gulf of St. Lawrence, James Bay, Hudson Bay and Ungava Bay, as well as Fox Basin and the Hudson Strait. In the biological, physical and chemical sciences, research activities have centred on the marine environment since responsibility for managing the freshwater fisheries and the anadromous and catadromous species in Quebec was delegated to the provincial government. However, the RSBQ does carry out projects in freshwater environments under special programs. These include studies on acid rain, effluents from the pulp and paper industry and research connected with the St. Lawrence Action Plan (SLAP). In the field of hydrography, the Branch is responsible for the navigable waterways in Quebec, particularly the St. Lawrence River east of Beauharnois, the St. Lawrence Estuary and the part of the Gulf of St. Lawrence which borders the Quebec coastline.

The RSBQ's mandate is to further knowledge in marine sciences in order to ensure the sustainable and ecologically sound management of fishery resources for the benefit of present and future generations. The Department is responsible for providing the federal government with scientific information to assist it in developing policies, regulations and legislation regarding the oceans and aquatic life. It is also responsible for making this information available to other federal departments, private industry and the public so that they can plan and carry out aquatic activities.

One of the RSBQ's main responsibilities involves providing fishery managers with scientific advice on the status of exploited fish stocks, invertebrates and algae as well as on

the state of the habitats on which aquatic organisms depend for their survival, in order to preserve them and ensure their productivity.

As we move into the 1990s, the situation of the marine fisheries in Quebec is a source of concern in light of the sharp decline in the commercial stocks of some species, such as cod; the increasing numbers of predators, such as seals and whales; and the many signs of serious anomalies in the ecosystem, such as the cooling of the Labrador Current and the proliferation of toxic algae. In addition, governments are becoming increasingly aware of the effects on the marine environment of the cumulative impact of hydroelectric power facilities, global warming caused by the greenhouse effect and the penetration of the water column by ultraviolet rays due to depletion of the ozone layer. To deal with this situation, it is imperative that scientific research be stepped up in order to determine the effects of these changes on the environment and on marine fisheries which is such an important resource for the fishing industry and the general public.

The research currently underway at the MLI addresses these major issues and is therefore of concern to the fishing industry. In 1991, in Quebec, the industry accounted for 10% of Canadian landings in the Atlantic area and about 10,500 jobs, 1,500 active vessels, $70 M worth of fishery resources and 110 buyers whose total production is valued at $190 M. It is vital that we learn the causes for the steady decline of catches in recent years, which have decreased by nearly 27% since 1987. MLI researchers monitor the stocks of several species exploited in the Gulf. Their work also affects the activities of fishermen in the other provinces of Eastern Canada, particularly the inshore fisheries, which will continue to be a key element of the industry.

The Institute holds primary responsibility for assessing the stocks of a number of species in the Gulf, including cod in 4RS-3Pn, redfish, Greenland halibut, herring in 4RS, capelin, mackerel, shrimp, and snow crab in 4S, as well as several inshore species in Quebec, such as lobster, rock crab and molluscs. Between now and 1996, we will continue to assess these stocks while seeking to develop new assessment methods, such as, for example, acoustic techniques for pelagic species. Sustaining a strong effort in this area, and working in close co-operation with colleagues from other DFO research centres, will allow us in the second half of the decade to start using acoustics as the standard method for assessing certain species, such as shrimp and capelin. The financial resources provided by the Atlantic Fisheries Adjustment Program (AFAP) will allow us to participate in the re-establishment of cod in the northern part of the Gulf of St. Lawrence, and the additional resources of the Quebec Federal Fisheries Development Program (QFFDP) will also make it possible to evaluate the abundance of underutilized species.

At the same time, research on recruitment methods will be increased in order to better understand the factors that contribute to higher survival rates among juvenile fish of the main

commercial species. This work will involve close co-operation with oceanographers since little is presently known about the oceanography and the primary production processes of the Gulf. Through continued effort in this area, within 10 years we should be able to explain the natural fluctuations that occur in the stocks of many of the species exploited in the Gulf. This should facilitate management of those species.

Intensive research on the interactions between commercial species, marine mammals and parasites will continue thanks to the expertise being developed on whales and seals and to the presence at the MLI of the Centre of Disciplinary Expertise for Parasitology. By 1996, through concerted inter-regional effort, the impact of these species on the resource will be more precise as will the estimate of the number of grey seals and harp seals that breed in the Gulf. The abundance and distribution of whales, including belugas, and their impact on the fisheries will be documented, considering their importance in the development of tourism and their predation of fishery resources. In order to counter the sealworm, its biology will be better understood, particularly the initial stages of larval development, and the invertebrates that serve as intermediary hosts for this parasite will be better identified.

In aquaculture, studies will be carried out on the mussel yield per mesh tube and on optimal socking density in order to promptly transfer the acquired knowledge to the industry. Over a longer term, test farming of cod and snow crab will be carried out to identify the most economical methods. In the medium term, the restaurant market may be interested in quality products that are available year-round. The initial results for cod show tolerance at low salinity and oxygen levels and promising growth rates.

The oceanographical activities will contribute to Canadian research being carried out under major international programs, such as Joint Global Ocean Flux Studies (JGOFS) and World Ocean Circulation Experiment (WOCE), which are aimed at studying the consequences of global warming. The extent of carbon absorption in the Arctic will be determined through a joint Canada/Japan program involving researchers at the MLI, several universities in Quebec and several Japanese institutes. Furthermore, the development of better measurement tools will continue. Working in co-operation with German researchers and private sector firms in Canada, this should lead to the development of an airborne LIDAR system to measure the productivity of inshore resources by 1996. This research should also lead to a wider use of flow cytometry to study particulate matter in the water column. These activities will take place in the Gulf and in Arctic regions and will require close co-operation among chemists, physicists and biologists.

A large-scale oceanography initiative will be the launching of a major project in Northern Quebec to better understand the impacts of the hydroelectric power facilities on James Bay, Hudson Bay and the Hudson Strait. This new project will draw on the expertise of departmental staff in other regions as well as the expertise of a number of partners in

universities and other federal and provincial departments. This program will require about 10 years and will furnish essential information to habitat managers relative to the assessment of cumulative impacts.

The other planned studies relating to fish habitat involve describing the characteristics and ongoing processes in various types of environments. The results will be used to provide advice for fishery managers. During the period of this plan, models of energy and material flow in planktonic trophic webs will be developed in order to understand habitat production mechanisms and identify the elements most vulnerable to disruptions by human activity. Models for assessing habitat quality will be developed as well. Research will continue on the impact of discharges into the sea and ways to prevent the accidental introduction of exotic species transported in ships' ballast water. Habitat quality indicators will be selected to provide tools better suited to managers' needs. Finally, an integrated information system on habitats will be developed based on the more recent geomatic techniques.

Chemical oceanographers and toxicologists will play a central role in some of these projects. They will describe, for example, the transformations that contaminants undergo in the water column, at the water-sediment interface, and in sediments, where their toxicity may be altered. They will also contribute to the understanding of the dynamics of CO_2 and nutrients in both clean and polluted environments. The manner in which toxic substances move up the food chain and are absorbed by belugas in the St. Lawrence and Saguenay rivers is a key component of the program, which will be carried out with funding from the St. Lawrence Action Plan. Specialized, state of the art laboratories were recently set up at the MLI in such fields as benthocosm and ecotoxicology to support these studies.

The safety of marine transport in Quebec depends on the activities carried out by the Canadian Hydrographic Service Branch (CHSB), which is based at the MLI. CHSB works in close co-operation with those involved in updating nautical charts and other official navigational publications intended to ensure safe navigation in Quebec's waterways. Surveys will be conducted in the Montreal and Quebec City areas and on the Lower and Mid-North Shore in order to update various nautical charts. Charts on these regions and the Gaspé and the Îles-de-la-Madeleine will be published. These products will continue to be promoted through the CO-PILOT program to ensure mariners' safety. Considerable effort will be devoted to developing new technologies, particularly in marine geomatics, in order to produce digitized maps and to modernize the digital Permanent Gauge Water Level Network (PGWLN). This work will be carried out in accordance with the national Canadian Hydrographic Service (CHS) plan and with private sector participation.

These activities depend on the collaboration of numerous partners in Canada (the DFO's other regions, universities, other federal and provincial government departments), and researchers in other countries (France, Japan and Germany). The availability of suitable

work tools in laboratories and in the field, particularly research vessels, is a prerequisite for implementing this plan which is aimed first and foremost at learning more about the marine environment for the benefit of fishermen and mariners, whose activities depend on this environment as well as for the benefit of the general public, which consumes fishery products and is committed to conserving marine resources.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i

LIST OF FIGURES ix

LIST OF TABLES ix

1.0 INTRODUCTION 1

1.1 Objectives 1
1.2 Regional Science Branch - Quebec Region Mandate 1
1.3 Establishing the Maurice Lamontagne Institute 7
1.4 Consultation on priorities 7
1.5 Budgetary situation 8
1.6 Constraints to be considered 9
1.7 Research plan 9

2.0 SCIENTIFIC INFORMATION AND LIAISON STRATEGY 11

2.1 Background 11
2.2 Perspectives 14

3.0 BIOLOGICAL SCIENCES BRANCH 17

3.1 FISHERIES RESEARCH DIVISION 19

3.1.1 Stock assessment 19
3.1.2 Abundance surveys 20
3.1.3 Recruitment 21
3.1.4 Fisheries ecology 22
3.1.5 Fisheries oceanography 23
3.1.6 Reference collections 23
3.1.7 Atlantic Fisheries Adjustment Program 24
3.1.8 Quebec Federal Fisheries Development Program 24

3.2 BIOLOGICAL OCEANOGRAPHY DIVISION 24

3.2.1 Carbon flux and climate 26
3.2.2 Toxic and harmful algae 27
3.2.3 Recruitment and trophic relations 28
3.2.3.1 Structure of the ecosystems of the Gulf of St. Lawrence 29
3.2.3.2 Processes related to the recruitment and dynamics of populations of zooplankton, invertebrates and fish in various sub-regions of the Gulf 29
3.2.4 Northern Quebec 30
3.2.5 St. Lawrence Action Plan 32

3.3 AQUACULTURE, MARINE MAMMALS AND PARASITOLOGY DIVISION 33

3.3.1 Aquaculture research 33
3.3.1.1 Farming Atlantic cod 34
3.3.1.2 Farming snow crab 35

3.3.2 Marine mammals 36
3.3.3 Parasitology 38

3.4 FISH HABITAT DIVISION 39

3.4.1 Habitat research and evaluation 39
3.4.2 Long-Range Transport of Atmospheric Pollutants 42

3.5 SCIENTIFIC COMPUTING DIVISION 43

4.0 PHYSICAL AND CHEMICAL SCIENCES BRANCH 45

4.1 PHYSICAL OCEANOGRAPHY DIVISION 47

4.1.1 Estuary and Gulf of St. Lawrence 48
4.1.1.1 Coastal processes 49
4.1.1.2 Modelling and monitoring 50

4.1.2 Northern environments 51
4.1.2.1 Previous research 51
4.1.2.2 Future research 52

4.2 CHEMICAL OCEANOGRAPHY AND CONTAMINANTS DIVISION 53

4.2.1 Carbon and nutrients cycles in the Gulf of St. Lawrence 54
4.2.2 Chemistry of trace metals and nutrients 55
4.2.3 Marine organic chemistry 56
4.2.3.1 Anthropogenic organic compounds 57
4.2.3.2 Organic compounds of natural origin 58
4.2.4 Biochemistry, molecular biology and marine microbiology 58
4.2.5 Toxicology 60
4.2.5.1 Toxicology of the St. Lawrence system 61
4.2.6 Paleoceanography 62
4.2.7 Mathematical modelling 63

5.0 CANADIAN HYDROGRAPHIC SERVICE BRANCH 65

5.1 Service to clients 67
5.2 Hydrographic infostructure 68

APPENDIX 1: List of abbreviations 73

APPENDIX 2: List of symbols 79

LIST OF FIGURES

FIGURE 1: Organization Chart - Regional Science Branch - Quebec Region. 2

FIGURE 2: North Atlantic Fisheries Organization Divisions, East Coast of Canada. 5

FIGURE 3: Regions of Canada where the Maurice Lamontagne Institute will carry on its major research work during the period 1992-1996. 6

FIGURE 4: Operational Structure - Scientific Information and Liaison Strategy. 12

FIGURE 5: Fields and areas of activity of the Biological Sciences Branch and allocation of personnel. 18

FIGURE 6: Fields and areas of activity of the Physical and Chemical Sciences Branch and allocation of personnel. 46

FIGURE 7: Fields and areas of activity of the Canadian Hydrographic Service Branch and allocation of personnel. 66

FIGURE 8: Map production planned by the Canadian Hydrographic Service Branch, 1992-1996. 71

LIST OF TABLES

TABLE 1: Fisheries research mandate of the Regional Science Branch - Quebec Region for the Gulf of St. Lawrence, and shared responsibilities with the Gulf Region. 4

TABLE 2: Project planning at the Canadian Hydrographic Service Branch, 1992-1996. 70

INTRODUCTION

1.1 Objectives

This document presents the major research orientations in the biological, physical and chemical sciences and hydrography proposed by the Regional Science Branch - Quebec Region (RSBQ) for the period 1992-1996. It is intended to serve as a guide for researchers and managers in the selection of research activities and will give other DFO regions insight into the priority research avenues of RSBQ personnel. These avenues remain closely linked to the scientific mission of the Department of Fisheries and Oceans (DFO).

1.2 Regional Science Branch - Quebec Region Mandate

The Science Sector of the Department of Fisheries and Oceans is responsible for advancing the knowledge of marine sciences to permit sustainable and ecologically sound management of ocean resources for the benefit of present and future generations of Canadians. The DFO's research activities should, more specifically, meet the many needs of the country's fishing industry. In this mission, the Department is responsible for providing the most accurate scientific information possible to the Canadian government to assist it in developing policies, legislation and regulations on oceans and aquatic life, and to other federal departments, private industry and the public to enable them to plan and carry out activities in the marine environment.

The Science Sector covers three main areas: Biological Sciences, Physical and Chemical Sciences, and Hydrography. Many multidisciplinary projects are made possible through the collaboration between scientists working in one of these three areas.

In the Biological Sciences, the DFO carries out short- and long-term research on fish and invertebrates as well as on marine mammals, plants and ecosystems. Its goal is to acquire knowledge and provide advice for the sound management and development of Canadian fisheries.

Physical and Chemical Sciences involve the study of the physical and chemical properties of oceans and the processes and phenomena which characterize them, the study of the behaviour of organic and inorganic bodies and their influence on fish and ecosystems, and the study of pollutants. The purpose of this is to provide information and advice to the private and public sectors, including regulatory bodies. Oceanographic technology and material are developed and transferred to the oceanographic industry.

DEPARTMENT OF FISHERIES AND OCEANS
REGIONAL SCIENCE BRANCH - QUEBEC REGION

Fiscal Year 1992-93

- Science Program (base budget) 194.40 P/Y
- Special Programs SLAP, AFAP, QFFDP, LRTAP, EARP, GREEN PLAN 8.25 P/Y
- Technical support, Sciences (base budget) 23.00 P/Y
- Total (RSBQ) 229.65 P/Y

APRIL 1992

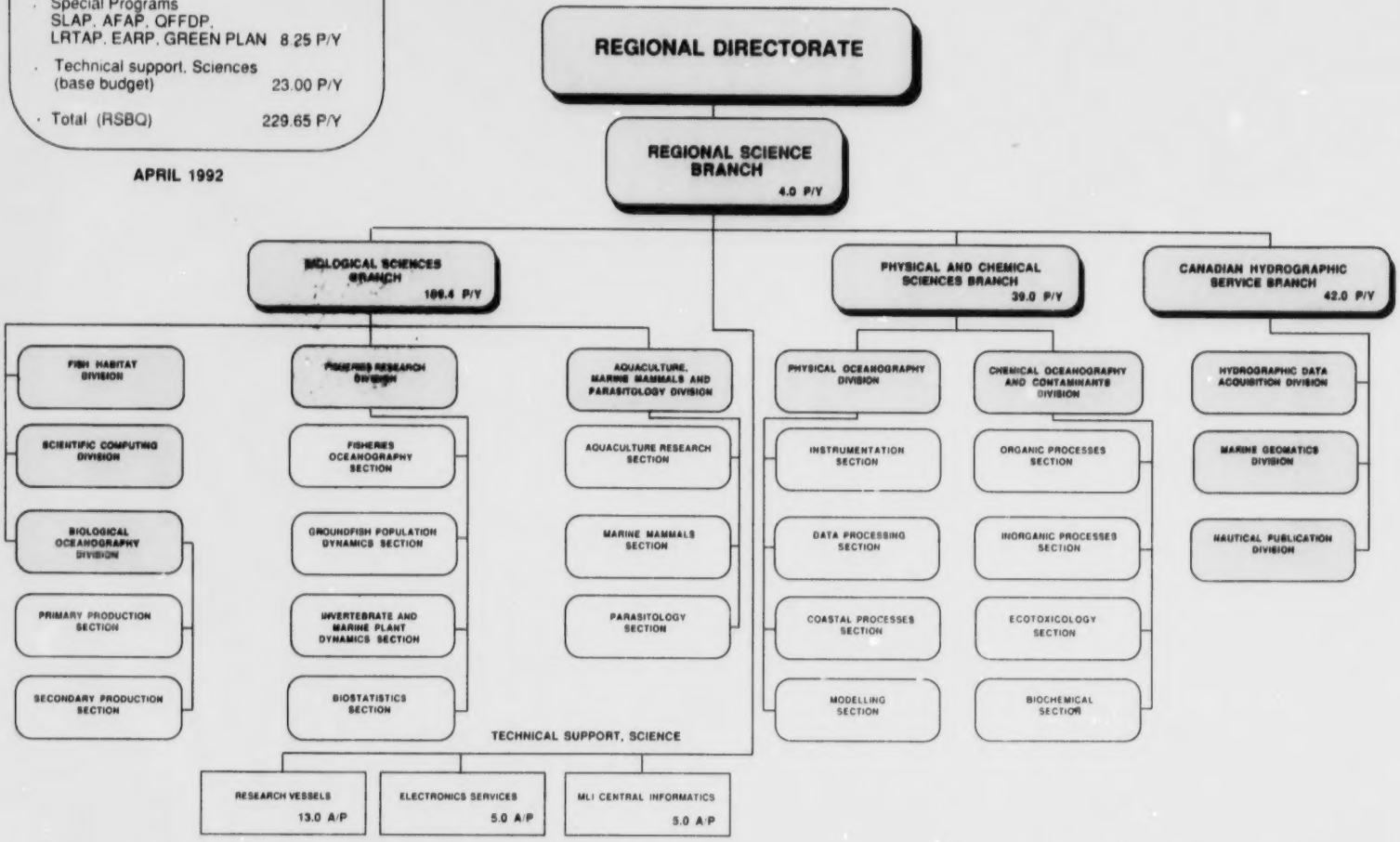

FIGURE 1 : Organization Chart - Regional Science Branch - Quebec Region.

Hydrography includes bathymetric and hydrographic surveys, tide and current readings and the production and distribution of nautical charts, tide and current tables, sailing directions and related publications under the auspices of the Canadian Hydrographic Service (CHS). These activities facilitate the use of waterways and ensure safer navigation.

One constant in all these scientific activities is the development of new technologies, particularly in the areas of aquaculture and resource enhancement, ocean sciences and hydrography. These new technologies have proven their worth and the oceanic industry in Canada has benefited considerably from them.

The mandate of the Regional Science Branch - Quebec Region covers the three areas of the Department's Science Sector: Biological Sciences, Physical and Chemical Sciences, and Hydrography (FIGURE 1). Since December 1986, work in connection with this mandate has been carried out at the Maurice Lamontagne Institute (MLI) in Mont Joli, the DFO's newest marine sciences research centre.

The MLI team of researchers, biologists, physicists, chemists, surveyors, computer specialists, etc. as well as the technical and administrative support staff already exceed 250. Researchers from other federal and provincial departments, various universities and foreign countries also participate in the work of the Institute.

The territory encompassed by the Quebec Science team is vast and diversified. It covers primarily the St. Lawrence Estuary and the Gulf of St. Lawrence, as well as the waters bordering Northern Quebec and the eastern Canadian Arctic. Following the integration of DFO Science programs in 1986, the research area assigned to the MLI is divided as follows : for Biological Sciences, it includes the Estuary and Gulf of St. Lawrence (the assessment of fish stocks in the Gulf is shared with the Moncton laboratory - TABLE 1 and FIGURE 2), as well as the coastal waters of Northern Quebec and those of Quebec as a whole for matters related to fish habitat and acid rain. Management of anadromous and catadromous species and freshwater fish in Quebec has been under provincial jurisdiction since 1922. The territory covered by Physical and Chemical Sciences includes the Estuary and Gulf of St. Lawrence as well as James, Hudson and Ungava Bays, the Hudson Strait and Foxe Basin. The Canadian Hydrographic Service is responsible for all the navigable waters of Quebec, particularly the St. Lawrence River from Beauharnois, the St. Lawrence Estuary and the part of the Gulf of St. Lawrence which borders the Quebec coastline (FIGURE 3).

RSBQ research projects dealing with the Gulf of St. Lawrence are carried out in close co-operation with the Gulf and Scotia-Fundy Regions, with the Central & Arctic Region participating in projects dealing with Northern Quebec and the eastern Canadian Arctic. The RSBQ is also involved in joint projects with all DFO regions.

TABLE 1: Fisheries research mandate of the Regional Science Branch - Quebec Region for the Gulf of St. Lawrence, and shared responsibilities with the Gulf Region.

RESEARCH	QUEBEC	GULF
Atlantic cod 4T	S	L
Atlantic cod 4RS-3Pn	L	S
White hake	S	L
Winter flounder	S	L
American plaise 4T	S	L
Witch flounder 4 RS	D	D
Greenland halibut	E	
Redfish sp.	L	S
Shark sp.	D	D
Atlantic mackerel	L	S
Atlantic herring 4R	L	S
Atlantic herring 4S	E	
Atlantic herring 4T	S	L
Capelin	L	S
American sand lance	D	D
Atlantic salmon	GQ	E
Other anadromous/catadromous species	GQ	D
Other fish	D	D
American lobster	D	D
Snow crab - Southwest of the Gulf	S	L
- Estuary and North Shore	E	
Rock crab	D	D
Pink shrimp	L	S
Scallop sp.	D	D
Other bivalves	D	D
Harp, grey, harbour and hooded seal	E	
Cetaceans	E	
Fishery ecology	L	S
Aquaculture and fish diseases	D	D
Parasites	L	S
Fish habitat	D	D

Key to symbols and mandates:

D: Decentralization of responsibilities; each region performs needed research within its boundaries
E: Exclusive; only one region responsible
GQ: Government of Quebec; the Quebec government is responsible for this research
L: Region with leading mandate; the other region has a subordinate role related to commitments such as sampling of catch
S: Subordinate role - see L above

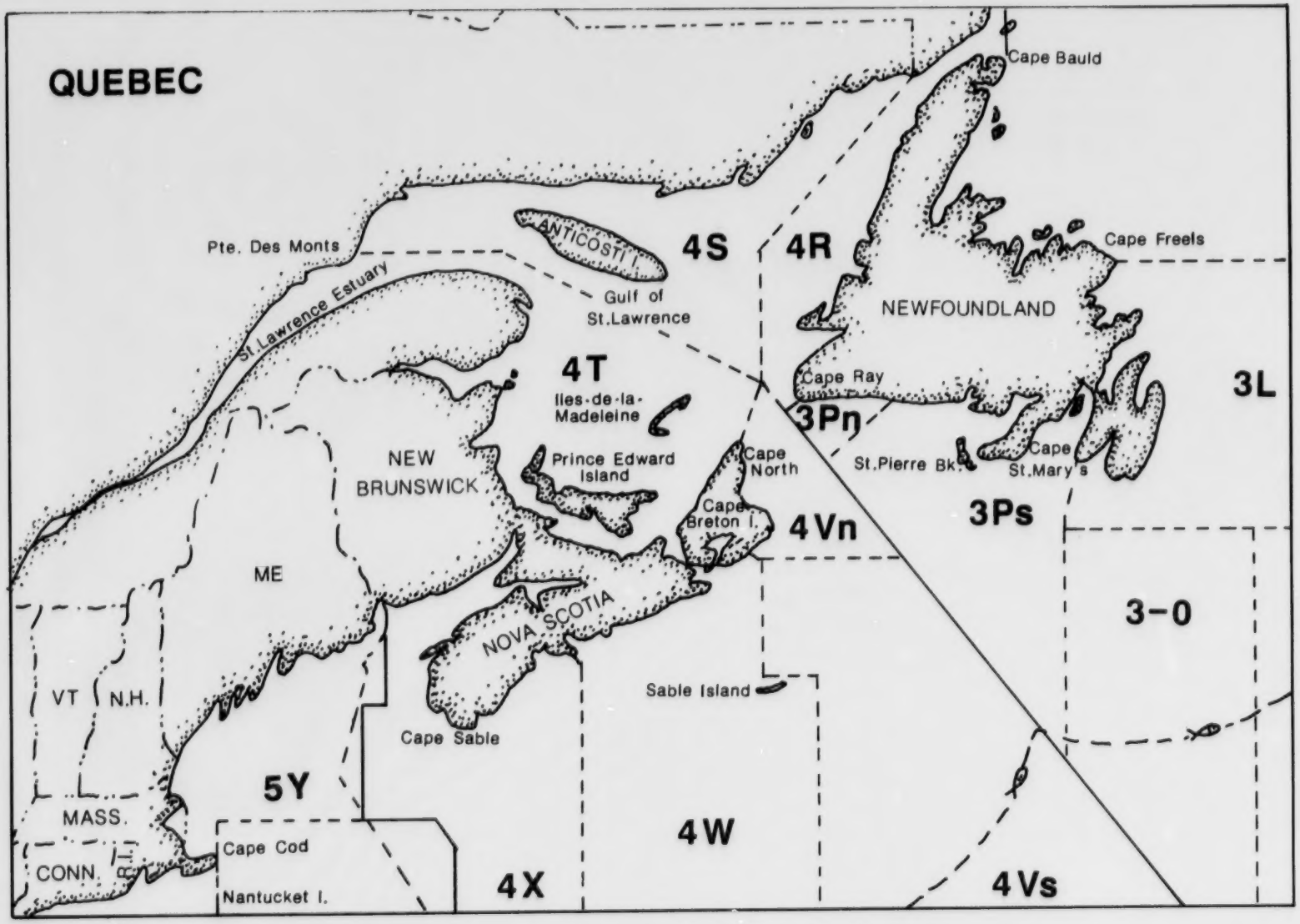

FIGURE 2 : North Atlantic Fisheries Organization Divisions, East Coast of Canada.

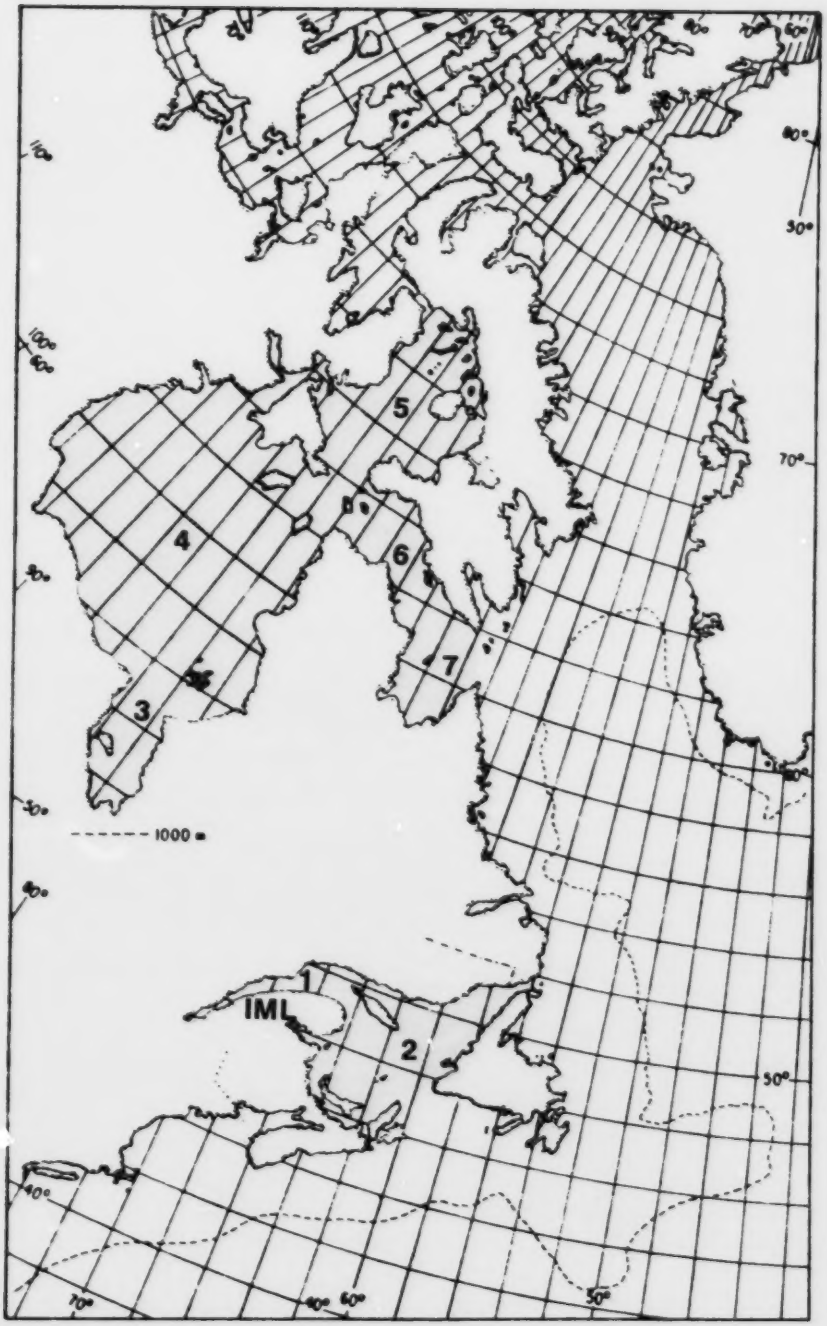

FIGURE 3: Regions of Canada where the Maurice Lamontagne Institute will carry on its major research work during the period 1992-1996 : 1) St. Lawrence Estuary, 2) Gulf of St. Lawrence, 3) James Bay, 4) Hudson Bay, 5) Foxe Basin, 6) Hudson Strait, 7) Ungava Bay.

1.3 Establishing the Maurice Lamontagne Institute

Since the opening of the Maurice Lamontagne Institute in 1986, efforts have dealt mainly with forming new research teams, the choice of specialization being guided by the mandates given to the MLI by the Department. A year and a half ago, a sufficient number of specialists was attained. Their presence allowed us to begin the outline of this report, which covers all Quebec Region research areas.

1.4 Consultation on priorities

The RSBQ consults regularly with its internal and external clients through a number of systems set up to establish research priorities on the basis of expressed needs. Among these are regular consultations by the three RSBQ branches with their respective client groups (fishermen, native groups in Northern Quebec, fishhing industry, other federal and provincial departments, representatives of the DFO Management Sector - Quebec Region, users of CHS products, etc.) and the annual information meeting on research priorities with all clients, particularly with representatives of the DFO's Gulf and Scotia-Fundy Regions. The RSBQ also carries out a major annual mail consultation on priorities with fishermen's associations, native groups, the fishing industry, universities, the DFO and other federal and provincial departments, for a total of 150 organizations. Other forms of consultation are carried out through committees such as the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC), the *Conseil de l'Aquiculture et des pêches du Québec (CAPQ)*, the Interdepartmental Committee on CHS Hydrographic Research, the US/Canada Cartography Committee and the US/Canada Hydrographic Commission. As well, peer review of RSBQ scientific programs and projects provides another form of consultation. In this way, the relevance of the research projects carried out by the RSBQ under the DFO mission is scrupulously examined.

To facilitate consultation on the major research avenues to be explored, two symposiums were organized to review the work carried out to date and to obtain a consensus in the scientific community about the research avenues that should be priorities for the DFO. The first, in March 1989, dealt with the Gulf of St. Lawrence, while the second, in November 1989, was on the Hudson Strait. Both brought together various experts from both inside and outside the DFO (collaborators, university researchers, other departments and clients). The proceedings of these conferences were published in the following documents:

Therriault, J.-C. (ed.). 1991. *The Gulf of St. Lawrence: Small Ocean or Big Estuary?* Can. Sp. Publ., Fish. & Aquat. Sci. 113: 359 p.

Percy, J.-A. (ed.). 1990. *Proceedings of a Workshop: Marine Ecosystem Studies in Hudson Strait.* 9-10 November 1989, Montreal, Que. Cdn. Tech. Rep., Fish. & Aquat. Sci. 1770: xiv + 175 p.

These publications contain numerous recommendations on research orientations, many of which have been taken into consideration in preparing this multi-year research plan.

A workshop on the effects of global warming on fisheries, held in Nanaimo in June 1990, led to the proposal of priority research areas for the DFO which have influenced the nature of the RSBQ's research work in the field. We should also mention the DFO's participation in the National Forum on the Future of the Beluga held in September 1988 in Tadoussac, where the RSBQ presented its five-year research plan on the beluga of the St. Lawrence and then invited participants to comment on this program.

Agreements with various federal and provincial departments, scientific organizations and educational institutions, as well as our participation in federal programs such as the St. Lawrence Action Plan (SLAP) and the Long-Range Transport of Atmospheric Pollutants (LRTAP), provided an opportunity for regular consultation with our partners on an impressive number of research activities carried out by the RSBQ under these agreements and programs.

It should also be noted that, for the past year, a project to intensify communications with the fishing industry has been underway, and we hope to see ties with this sector become even closer in the future (see Section 2.0).

1.5 Budgetary situation

It goes without saying that the success of the research plan is highly dependent on the continuing support of government for research in the important fields of fisheries and oceans to ensure that our activities continue in line with departmental priorities. The country's current financial situation calls for an innovative approach, coupled with the search for alternative sources of funding such as the development of partnerships with those working in the same areas.

Over the past seven years, the non-indexation of basic budgets has represented a 30% loss in buying power. However, this has been compensated by special temporary credits: the MLI start-up budget (ending in 1992-93); the Long-Range Transport of Atmospheric Pollutants Program (ending in 1996-97); and the St. Lawrence Action Plan (Phase I ending in 1992-93). The introduction of major new programs, including the Green Plan for Canada, the Quebec Federal Fisheries Development Program (QFFDP) and the Atlantic Fisheries Adjustment Program (AFAP), tends to confirm the trend towards investing public funds in specific programs of public interest rather than supporting departmental growth.

The RSBQ is seeking to respond to this new budgetary environment by aligning its priorities with those of the special programs, while maintaining close ties with the Department's mandate. This will enable us to respond to the government's invitation to carry out its priority programs while keeping the DFO's Science Sector mission in the forefront.

The RSBQ expects to be able to carry out most of its proposed projects if its budget is maintained in the $20 M range, including some 220 P/Y, and assuming that the special programs planned for the period 1992-96 are financed by the government.

1.6 Constraints to be considered

Funds for special programs will not permit us to purchase, maintain or replace the basic infrastructures and equipment essential to conducting scientific research activities. Compared to what is available in other well-established DFO administrative regions, the MLI has not yet obtained all the research vessels and computer systems needed to adequately fulfil its mandate. In particular, access to an adequate platform for work in the Gulf is an essential requirement, as is a central computer system sufficiently powerful to manage a national network of databases on fish habitat, currently fished stocks and the ocean environment.

Access to these resources, as well as to international activities and conferences, is an important consideration, given Canada's desire to become an active partner in major scientific initiatives linked to the future of the planet, such as the Joint Global Ocean Flux Studies (JGOFS) and the World Ocean Circulation Experiment (WOCE) programs.

1.7 Research plan

The multi-year research plan is based on the mandate given to the Maurice Lamontagne Institute by the Department during the review of responsibilities carried out in 1986. It describes the main research areas that the RSBQ wishes to cover in the next five years. It will be implemented gradually through the annual project planning process and the preparation of work plans, as well as through approval of budget envelopes allocated for each of the fiscal years covered by the plan. Fulfilling the plan will depend not only on the resources placed at our disposal, but also on our personnel's ability to carry out the various research programs and projects within a context of increasingly tight budgets while continuing to strive for scientific excellence, increasing the participation of under-represented groups, particularly women in science, and developing more tangible partnerships with our clients, including the fishing industry.

If this plan is to be realistic, we must also count on closely collaborating with our colleagues in the universities, government and the private sector. With regard to this, it should be mentioned that a number of scientific co-operation agreements have been signed with various organizations including the *Groupe interuniversitaire de recherches océanographiques du Québec (GIROQ)*, the *Université du Québec à Rimouski (UQAR)*, the *ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ)* and the *Institut français de recherche pour l'exploitation de la mer (IFREMER)*. Other agreements are currently being discussed.

We invite our colleagues and partners to read this document and to give us their suggestions and comments. These will be useful in making annual adjustments to this plan and will assist us in preparing the next multi-year plan.

SCIENTIFIC INFORMATION AND LIAISON STRATEGY

2.1 Background

During the summer of 1990, the Department of Fisheries and Oceans, Quebec Region, launched a pilot project with two basic objectives: to increase contacts between scientists and fishermen; and to disseminate the results of the work done in the biological sciences, the physical and chemical sciences, and hydrography at the Maurice Lamontagne Institute. The first objective is aimed at a specialized group (fishermen and other representatives from the fishing industry) with whom the Department has always wanted closer ties. The second objective addresses a highly diversified clientele which includes Department employees and senior management, partners and collaborators as well as the general public.

There are many reasons underlying this project. DFO senior management has expressed the desire for closer ties with those directly affected by its decisions and activities. In December 1989, the Scotia-Fundy Region Groundfish Task Force (Haché Report) recommended increased participation by fishermen, not only in DFO scientific activities but also in the departmental decision-making process. It is a well-known fact that DFO research centres are facing the common problems of interaction between scientists and clients, and lack of public awareness of the work done by scientists in those laboratories. With this in mind, DFO Quebec Region senior management decided to launch a scientific information and liaison pilot project which is in accordance with the Public Service 2000 philosophy. The Quebec Region volunteered to implement the project with its own existing resources and the approach will be exported to the other regions of the department if the experience turns out to be conclusive. As the achievement of these two fundamental objectives implies a profound organizational "cultural change", the daily duties of employees concerned by this initiative may need to undergo considerable adaptation. This will have to be anticipated.

Responsibility to design an implementation strategy has been given to the Maurice Lamontagne Institute Regional Science Branch - Quebec Region. Consultations were held with scientists, fishermen and other representatives from the fishing industry, DFO managers, fisheries officers, inspectors, the Canadian Atlantic Fisheries Scientific Advisory Committee, as well as the media and regional and local groups. These discussions were aimed at determining the expectations of MLI clients, particularly fishermen and others involved in fisheries, with respect to the Institute's scientific programs. This phase led to the preparation of a strategy to intensify contacts between fishermen and scientists and to familiarize the public with the work of the MLI. Three basic documents were prepared: *Maurice Lamontagne Institute, Context and Activities*; *Scientific Information and Liaison Strategy, Quebec Region, January 1991 - January 1993*; and *Implementation of Scientific Information and Liaison Strategy, April 1, 1991 - March 31, 1992*.

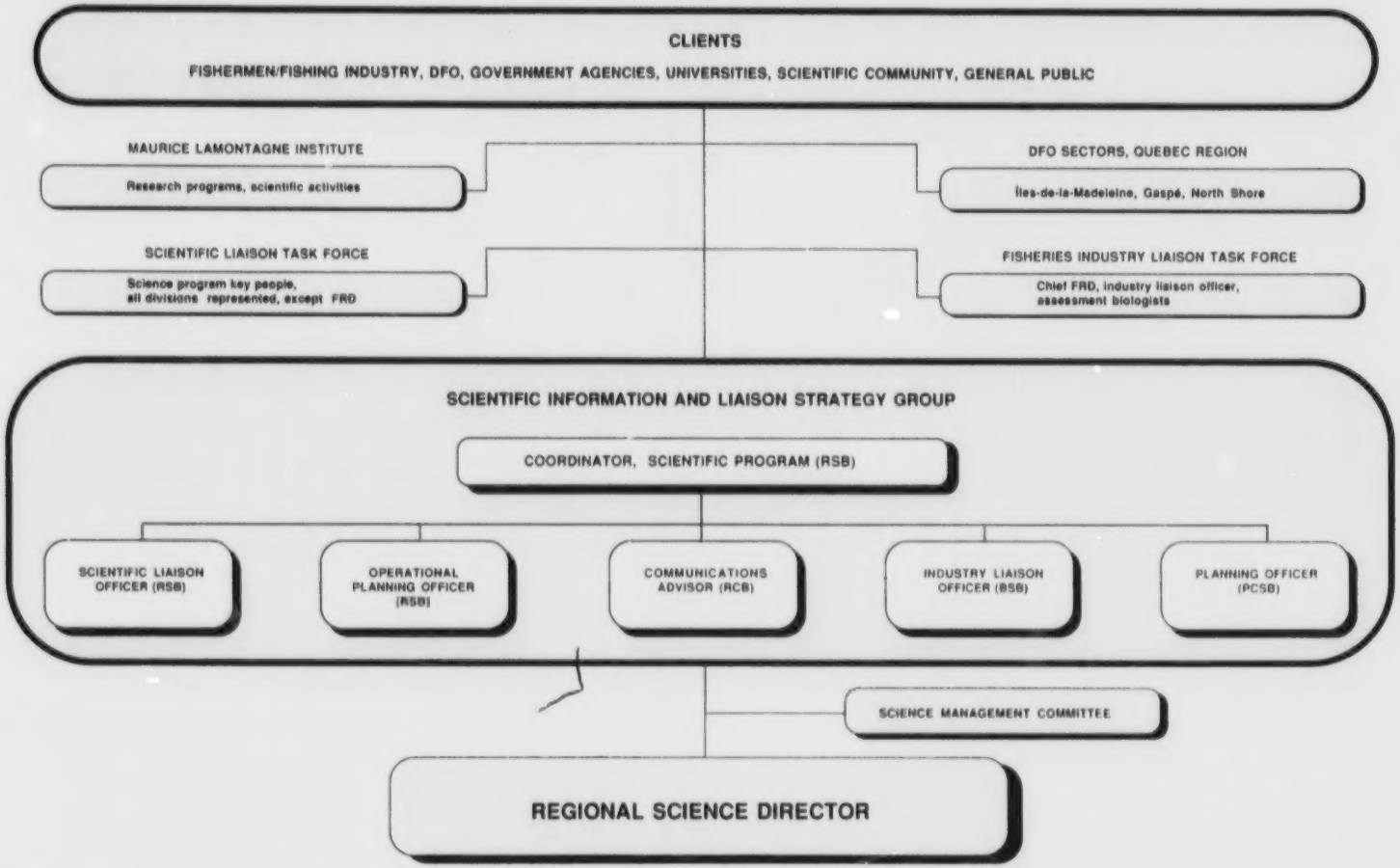
DEPARTMENT OF FISHERIES AND OCEANS
REGIONAL SCIENCE BRANCH - QUEBEC REGION
CLIENTS
FISHERMEN/FISHING INDUSTRY, DFO, GOVERNMENT AGENCIES, UNIVERSITIES, SCIENTIFIC COMMUNITY, GENERAL PUBLIC
MAURICE LAMONTAGNE INSTITUTE
Research programs, scientific activities
DFO SECTORS, QUEBEC REGION
Îles-de-la-Madeleine, Gaspé, North Shore
SCIENTIFIC LIAISON TASK FORCE
Science program key people, all divisions represented, except FRD
FISHERIES INDUSTRY LIAISON TASK FORCE
Chief FRD, industry liaison officer, assessment biologists
SCIENTIFIC INFORMATION AND LIAISON STRATEGY GROUP
COORDINATOR, SCIENTIFIC PROGRAM (RSB)
SCIENTIFIC LIAISON OFFICER (RSB)
OPERATIONAL PLANNING OFFICER (RSB)
COMMUNICATIONS ADVISOR (RCB)
INDUSTRY LIAISON OFFICER (BSB)
PLANNING OFFICER (PCSB)
SCIENCE MANAGEMENT COMMITTEE
REGIONAL SCIENCE DIRECTOR

FIGURE 4 : Operational Structure - Scientific Information and Liaison Strategy.

The first describes in layman's language the scientific work carried out at the MLI. These texts correspond to the information to be made available to MLI clients and the general public. The second is the detailed action plan of the strategy, i.e. the means used for making the general public aware of the work of the MLI and the measures that should be taken to bring scientists closer to fishermen and processors. The third document corresponds to the strategy work plan for the current fiscal year.

The Scientific Information and Liaison Strategy (the Strategy) was developed in close co-operation with all involved to ensure that the measures and methods chosen satisfy all those who must adapt to these changes in the future. Among the concrete steps already taken to strengthen links between fishermen and scientists are: the creation of new Index Fishermen programs (see Section 3.1.1) to enable the fishing industry to participate directly in stock assessment; the consultation of fishermen regarding the DFO's scientific research priorities; the participation of fishermen in scientific sampling missions; the carrying out of scientific missions aboard commercial fishing vessels; and finally, the production of a Canadian Industry Report of fisheries and Aquatic Sciences produced jointly with a fisherman.

Various means were employed to inform the public of the scientific work carried out at the MLI, for example: publication of the newsletter *Nouvelles des Sciences*; publication of articles describing the MLI's scientific activities in regional papers serving the Lower St. Lawrence, Gaspé, the Îles-de-la-Madeleine and the Quebec North Shore; publication of a regular MLI column in a Rimouski area paper, preparation of articles for the periodicals *Pisces* and *Pêche Impact* as well as the journal *L'Euskarien*; preparation of various science documents written in layman's language including *Guide to the St. Lawrence Lower Estuary*, a document for the general public which will be published in 1992, and *Maurice Lamontagne Institute, Marine Sciences Research Centre*, which will be the official promotional document given to our partners and clients.

All these activities require considerable work by many employees in different Quebec Region sectors, such as the Regional Science Branch (RSB), the Biological Sciences Branch (BSB), the Physical and Chemical Sciences Branch,(PCSB) the Canadian Hydrographic Service Branch (CHSB), the Regional Communications Branch (RCB) and in the future by the DFO's Quebec Region sector offices.

In addition, to manage and implement the Strategy, a number of teams, under the operational supervision of the Regional Science Director, were formed (FIGURE 4): the Scientific Information and Liaison Strategy Group coordinates all activities related to the Strategy; the Fishing Industry Liaison Task Force is responsible for establishing procedures to increase communication between fishermen/fishing industry and the biologists responsible for assessing stocks; the Scientific Liaison Task Force brings together individuals from the three MLI scientific programs and its main role is to provide guidance and advice on the means used for publicizing the work of the Institute.

The Internal Audit and Evaluation Branch in Ottawa will hold an official review of Strategy activities in January 1993. In the meantime, the Scientific Information and Liaison Strategy Group will report regularly on the activities and the progress of the Strategy to DFO senior management.

2.2 Perspectives

As part of the Regional Science Branch - Quebec Region multi-year plan, the activities of the Scientific Information and Liaison Strategy are described as follows:

- **Activities to forge closer ties with our clients, particularly fishermen and the fishing industry**

  . Setting up new Index Fishermen programs (see Section 3.1.1);

  . Increasing the participation of fishermen and other representatives from the fishing industry in scientific missions and stock assessment as well as the participation of assessment biologists in fishing activities;

  . Increasing the frequency of discussions with fishermen and diversifying the means of communication;

  . Producing documents in layman's terms about our research programs on fisheries and data prepared for CAFSAC, specifically those destined for fishermen and the fishing industry;

  . Periodically producing an information bulletin for fishermen participating in the Index Fishermen Program;

  . Maintaining close co-operation with the aquaculture industry;

  . Organizing tours whereby pertinent Quebec Region managers consult fishermen and other representatives from the fishing industry;

  . Implementing an overall client consultation process and follow-up procedures.

- **Activities to increase awareness and understanding of our scientific work inside and outside the Department**

  . Producing and publishing a five-year summary (December1986 - March 1992) of MLI scientific activities;

. Producing the newsletter *Nouvelles des Sciences* for our research partners;

. Preparing the MLI column for a Rimouski area weekly;

. Publishing articles for the general public in regional papers serving the coastal areas of the entire Gulf of St. Lawrence region and in scientific magazines and periodicals;

. Producing scientific material in layman's terms, for the student population of Quebec's maritime regions;

. Producing scientific material in layman's terms, for fisheries officers and inspectors and sampling technicians who are in direct contact with our clients;

. Promoting the navigation aids produced by the Canadian Hydrographic Service Branch (CHSB), particularly among fishermen;

. Developing a more "pro-active" attitude to MLI media visibility by negotiating production projects dealing with our scientific work;

. Maintaining activities for the general public, such as open houses and guided scientific tours.

- **Activities related to management of the Strategy**

. Producing monthly reports for managers in the Science Sector about activities related to the Strategy's implementation;

. Preparing reports for DFO senior management which will describe progress made in implementing the Strategy and the expected results;

. Setting up and managing a data collection system on all MLI media activities;

. Updating the Scientific Information and Liaison Strategy work plan and preparing the budget;

. Preparing the general review of Strategy activities from January 1991 to December 1992 for examination by the Internal Audit and Evaluation Branch.

Since the implementation of the Scientific Information and Liaison Strategy is the concern of all MLI employees, activities under this Strategy will increasingly form an integral part of each employee's daily duties, thus ensuring the success and sustainability of the undertaking. The size of the current organizational structure of the Strategy will be reduced gradually until March 1993, when its implementation will become the entire responsibility of managers.

BIOLOGICAL SCIENCES BRANCH

The research mandate of the Biological Sciences Branch (BSB) covers the St. Lawrence Estuary, the Gulf of St. Lawrence and Northern Quebec. The Branch provides advice on the management of a large number of stocks of fish, invertebrates, marine plants and marine mammals. It assumes a leadership role in mackerel research in the Atlantic as well as in shrimp and redfish research. It carries on research aimed at identifying the factors governing the recruitment and the effects of climate changes on marine resources. In co-operation with the other DFO Atlantic regions, it maintains a research and monitoring program on toxic algae. It carries out research on aquaculture in order to provide support to the industry. It studies the effects of man-made disturbances and provides the advice necessary to protect fish habitat. It is also responsible for the Department's Centre of Disciplinary Expertise for Parasitology.

The Branch also participates in carrying out major national, departmental and interdepartmental programs such as the Atlantic Fisheries Adjustment Program, the Quebec Federal Fisheries Development Program, the St. Lawrence Action Plan and the Long-Range Transport of Atmospheric Pollutants Program.

The Biological Sciences Branch comprises five divisions (FIGURE 1 and FIGURE 5): Fisheries Research; Biological Oceanography; Aquaculture, Marine Mammals and Parasitology; Fish Habitat; and Scientific Computing. Its main clients are DFO managers, other federal departments (e.g. Environment Canada) and provincial departments (e.g. *ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec - MAPAQ* and *ministère de l'Environnement du Québec - MENVIQ*), the fishing industry and native associations (Makivik, Grand Council of the Crees). Under its research mandate, the Branch communicates the results of its research to the national and international scientific community.

The uncertain future of the fisheries industry, its increased media visibility through the crises of recent years, its economic importance for coastal communities, the growing public expectations with regard to the environment, the quality and safety of fishery products and the reliability of scientific data are all determining factors in the selection of priorities for the Biological Sciences Branch.

The BSB multi-year research plan is based on consultations with its clients, as well as on the priorities identified by the Department of Fisheries and Oceans.

Over the coming years, the Branch will devote considerable effort to increasing the frequency and quality of communications with the fisheries industry in order to make it aware of the various

FISCAL YEAR 1992-93
Biological Sciences: 109.4 P/Y (Base)

DEPARTMENT OF FISHERIES AND OCEANS
REGIONAL SCIENCE BRANCH
QUEBEC REGION

APRIL 1992

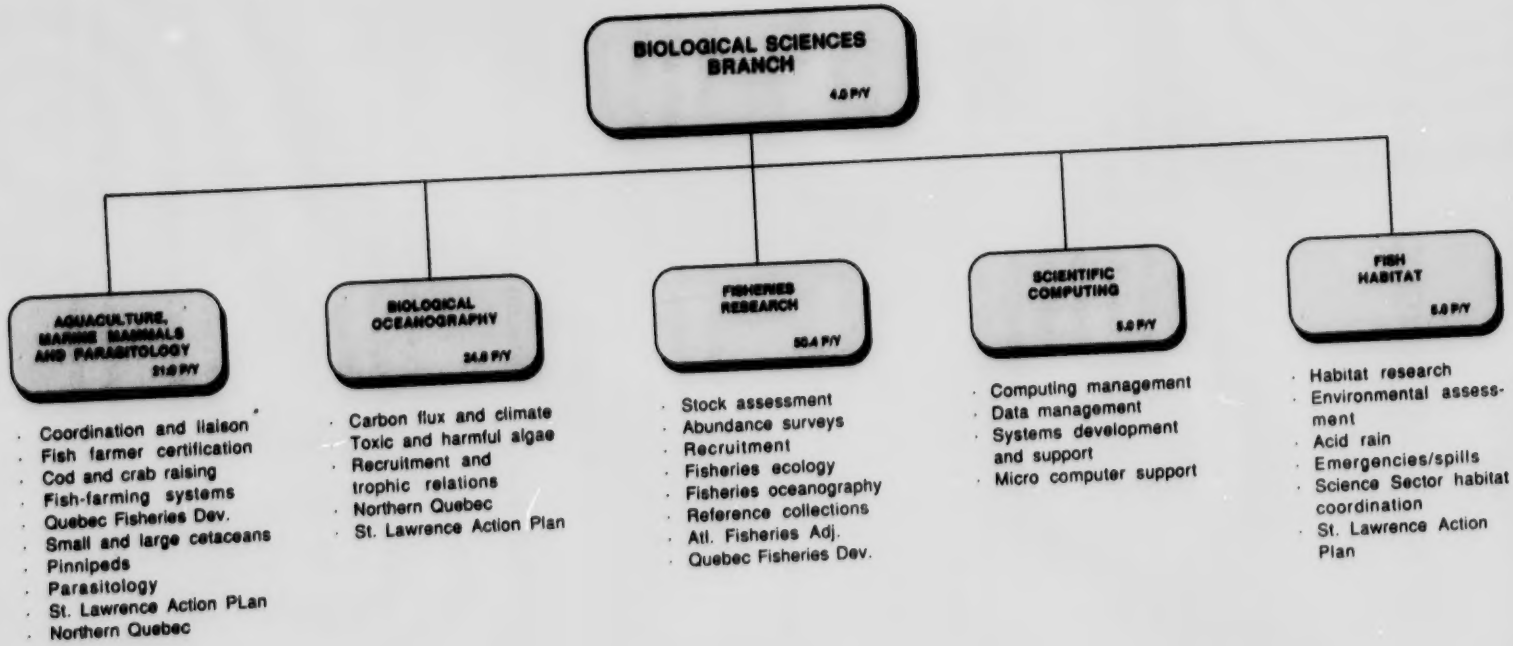

FIGURE 5 : Fields and areas of activity of the Biological Sciences Branch and allocation of personnel.

problems related to the instability of certain stocks and of the important role that its co-operation and active participation plays in increasing the accuracy of stock assessment and management advice.

Research will also be undertaken on the growth of the seal population and on the impact of this phenomenon and of seal parasites on the fishing industry. The beluga whales of the St. Lawrence will again receive particular attention because of the close link between their survival and the decontamination of the St. Lawrence.

The protection and conservation of fishery resources and their habitat will again receive all the necessary consideration, and research already begun on the phenomenon of world climate change will continue in order to determine the impact on maritime resources. The BSB will also closely monitor the hydroelectric development projects to be undertaken in Northern Quebec over the coming years.

3.1 FISHERIES RESEARCH DIVISION

Fisheries research is aimed at gaining a better understanding of the parameters governing fisheries in the St. Lawrence Estuary and the Gulf of St. Lawrence as well as in Northern Quebec, and at formulating the scientific advice needed for the management of fisheries resources. There are two main components involved: (1) assessment of stocks in terms of abundance and production, and present and potential catches; (2) fundamental research on the biological and environmental factors affecting the recruitment, growth, mortality, distribution and availability of exploitable populations.

The main species for which the Fisheries Research Division (FRD) is responsible are: cod, redfish, herring, mackerel, capelin, turbot, shrimp, snow crab, lobster, scallop, mussel, rock crab, whelk and brown algae (rockweed and kelp).

3.1.1 Stock assessment

Stock assessment is the basis of the system for managing marine resources fished by commercial and sports fishermen. Reviews are done regularly to inform and advise Department managers and the fishing industry of the biological status of resources and the impact of management measures on stocks. The objective is to provide high-quality advice by using the latest methods and developing new approaches.

Analytical assessment of stocks of cod (4RS-3Pn), redfish (4RST), herring (4R), and mackerel, as well as biological monitoring of other stocks of interest will continue. An accelerated research program on cod (see Section 3.1.7) will also be maintained to improve our assessment capacity. Joint studies will continue with biologists from the Newfoundland and Scotia-Fundy Regions on

discrimination of redfish stocks in region 3P-4RSTV. The work already undertaken on discrimination of turbot stocks and the analytical assessment of this species in the Gulf will be completed.

The Division will continue the assessment of stocks of shrimp (Gulf), snow crab (Estuary and Northern Gulf), lobster (Îles-de-la-Madeleine and Anticosti Island) and sea and Iceland scallop (Îles-de-la-Madeleine and Northern Gulf). The usefulness of sequential population analyses based on shrimp length frequencies will be assessed. The minimum legal length for an optimum yield per recruit at current lobster fishing levels will be determined. Time series analyses will be made of abundance, capturability, and recruitment of snow crab in the different management zones.

Sampling of commercial catches is an integral part of stock assessment. This program is constantly being updated in response to assessment requirements and fishing operations. An integrated computer system will be set up for the collection, validation, analysis and storage of these data. This system will considerably improve the control of sampling as well as access to data.

At the same time, the Index Fishermen Program, which initially dealt only with herring (4R) and cod (4RS-3Pn), will be extended to rock crab (Chaleur Bay and the Îles-de-la-Madeleine), Greenland halibut (4ST), herring (4S), mackerel (4Vn-4T) and turbot (3Pn) for the period covered by this plan. Over a hundred fishermen will work with MLI biologists to assess stocks. In the coming years the FRD plans to implement Index Fishermen programs for snow crab in the St. Lawrence Estuary and the Northern Gulf, for shrimp and capelin in divisions 4R, 4S and 4T and for mackerel in divisions 4R and 4S.

The ability to determine the age of fish and invertebrates is a fundamental element of stock assessment and fisheries research. The Division will take the necessary steps to ensure accuracy and coherence in this activity.

3.1.2 Abundance surveys

The Division carries out regular surveys for the abundance of different stocks and looks for appropriate areas for the development of new resources. It also strives to improve sampling methods, equipment, procedures and analysis methods.

The shrimp-redfish-cod survey will be launched with a new trawl, an analysis of comparative missions and the implementation of a new sampling scheme. Assessment of mackerel in eastern Canada will, in the years to come, take on a new direction based on an estimate of "batch" fecundity. Another goal is the establishment of a reliable index of recruitment of snow crab based on trawler surveys.

The Division will increase its research initiatives using hydroacoustic techniques and determine the methods needed to estimate the abundance of herring, mackerel and capelin during hydroacoustic surveys. Work has also begun on developing an automatic method for identifying fish species, molluscs, and crustaceans using acoustic signals. To improve our ability to locate mackerel schools, the potential of aerial detection will be examined.

3.1.3 Recruitment

The goal of this program is to study the main factors that control the growth and mortality of marine populations in the larval and juvenile stages and to determine their importance for the recruitment of commercial populations. FRD projects will complement those of the Biological Oceanography Division (see Section 3.2).

The program will continue to study the relationship between the physiological condition of shrimp larvae and their chances of survival through a series of laboratory studies on the value of fat reserves as an indicator of their condition. An oceanographic mission will serve to check and validate the applicability of an index developed in the laboratory on larvae taken in the natural environment.

The FRD is participating in a France-Canada joint project with the *Institut français de recherche pour l'exploitation de la mer (IFREMER)* as part of the IREP (International Recruitment Experiment Program), for the International Council for Exploitation of the Sea (ICES), which will end in 1992 with the publication of a second article on factors determining sole recruitment in the Bay of Biscay.

The last field season of a project aimed at determining the usefulness of the microstructure of otoliths for the study of the growth and survival of northern fish larvae was completed in 1990, and data processing and preparation of publications are now taking place.

A new program dealing mainly with cod in the Northern Gulf of St. Lawrence was launched in 1991. General objectives are the study of the factors influencing the distribution and growth of juveniles, as well as the involvement of different nurseries in the formation of age classes. Field operations began in 1991 and their progress will be assessed in 1993.

In order to define the role played by the juvenile stage in determining recruitment of mackerel, work on assessing the growth-mortality relationship and the importance of cannibalism during the first year of life will continue until 1994, through a study of the phenomena influencing the co-distribution of juveniles and adults. In this context, the analysis of the microstructure of otoliths undertaken to better understand the control of juvenile growth and the relationships between the two reproductive groups is scheduled for completion in 1992.

Research carried out since 1986 by the Fisheries Research Division has shown that brief exposure to dinoflagellate toxins may cause massive mortality in fish larvae without affecting invertebrates. The current phase should be completed in 1994 with a description of the evolution of toxins in natural plankton communities and the influence of toxic algae on the structure of these communities.

The ecological characteristics of lobster larvae will be defined and used in a digital model of the hydrodynamics of the Magdalen Shelf to pinpoint the key factors controlling recruitment and to check on the forecasting power of the Îles-de-la-Madeleine landings.

The reproductive cycle and spatiotemporal variability in the success of detecting sea scallop spat will be studied in the Îles-de-la-Madeleine. We will also be analysing the reproductive cycle in the lagoon environment. Particular attention will be paid to the description and geographical distribution of scallop habitat in the Northern Gulf (Iceland scallops).

The monitoring of trends in the B-N diagram (biomass VS number), a study begun in the Îles-de-la-Madeleine in 1990, will continue. The growth, mortality, dispersion and migration of experimental seeding as well as its predators and the predation rate on seed will be examined under the Program *REPERE - Recherche sur les pectinidés à des fins d'élevage et de repeuplement*.

3.1.4 Fisheries ecology

This program is aimed at the study and understanding of the basic ecology of commercial resources and the development of management strategies that take these characteristics into account. It also examines the reaction of populations to fishing and considers how this new information can be used to improve management of the resource.

The FRD will be determining the scientific bases necessary for the formulation of a management strategy for underutilized species, taking into account the profitability of fishing and the survival of stocks. With regard to this, the best strategy for cutting *Ascophyllum* will be determined, and a harvesting strategy aimed at decreasing the catch of immature whelk of sublegal size will be recommended. As well, a rock crab management strategy that takes into account the possible relations between this species and lobster will be developed.

The Saguenay Fjord is home to many species of interest which are not commercially fished, since commercial fishing was interrupted in the early 1970s due to severe mercury contamination. The Saguenay is therefore a unique area for studying the biology and dynamics of these species, small-scale mechanisms for genetic differentiation and the dynamics of contaminants in the food chain.

Research is also planned on snow crab. This work will deal with the impact of current strategies to manage the size structure and the demographic composition of populations being fished, by

comparing Gulf populations to those of the Saguenay. Some efforts will also be directed at studying the phenotype and genotype effects of chronic contamination by industrial contaminants (Hg, PCBs).

Several projects will increase our knowledge of commercially fished shrimp populations in the Gulf. An attempt will be made to determine the effects of fishing on the growth and sexual inversion of individuals and to develop a management strategy for this species. The development of reliable abundance indices for commercial fishing will also be undertaken. A virgin population (Saguenay) of shrimp will be described to better understand the effects of commercial fishing on other populations.

A modelling exercise will be carried out on the dispersion of scallop gametes. The critical distance between genitors for breeding success will be studied and the predictions of the model will be compared to observations. This will help to solve the problem of overfishing the breeding potential.

The yield per growing stock and the optimum density per sock for mussels will be studied. A stock-site test will be undertaken in the Îles-de-la-Madeleine. Feeding behaviour in terms of the presence of toxic dinoflagellates will also be studied.

3.1.5 Fisheries oceanography

This program will study the relation between the environment and the distribution of stocks, the distribution and migration of individuals, and the productivity of populations.

The joint studies undertaken by MLI oceanographer-biologists and researchers from the Scotia-Fundy and Newfoundland Regions on the effect of environmental conditions on the distribution of redfish will continue.

To obtain a better understanding of mackerel movements in the Gulf, we will be analyzing an acoustic database on the movements of this species based on hydrodynamic conditions (Lower North Shore). An experimental study of migration mechanisms in mackerel was undertaken in 1991-1992.

A description will be made of the aggregation dynamics of organisms in the northwestern Gulf, an area known for its rich fisheries resources and its populations of whales.

3.1.6 Reference collections

The work of consolidating and developing the various reference collections will continue on an annual basis. Taxonomic consultation, donations and exchanges of specimens will be offered

to the scientific community. A study begun in 1990 to characterize and describe the benthic fauna of the Saguenay will continue throughout 1993-1994.

3.1.7 Atlantic Fisheries Adjustment Program

The Atlantic Fisheries Adjustment Program (AFAP) is aimed at ensuring the long-term viability of the fishery. Announced in May 1990 by Fisheries and Oceans Minister Bernard Valcourt, this five-year program directly affects fisheries research, since its goal is to re-establish cod in the northern Gulf of St. Lawrence. Projects will specifically target improving the accuracy of fisheries data and the participation of fishermen in the scientific research conducted by the DFO. Our work plan comprises five components: coastal migration, discrimination of stocks, the observer program, research surveys and research in coastal waters, and the computer-related aspect. Begun in 1990-91, the AFAP program became fully operative during the 1991-1992 fiscal year.

3.1.8 Quebec Federal Fisheries Development Program

Announced in August 1990 by Fisheries and Oceans Minister, Bernard Valcourt, the Quebec Federal Fisheries Development Program (QFFDP) is aimed at restructuring the Quebec fishing industry on a sustainable basis. Key elements of this program are the increase of marine resources available to the industry as well as the stability of traditional fisheries. A research budget of $10.5 M has been allocated for this purpose under the QFFDP for the period 1991-1995.

Research programs will be geared to the development of fisheries for underutilized species such as mackerel, 4S herring, capelin, skate, dogfish, monkfish, rock crab and Stimpson's surf clam, as well as to the stabilization and reconstruction of stocks of species in difficulty such as 4RS-3Pn cod, turbot, snow crab and scallop.

Program design and implementation will proceed in close co-operation with the fishing industry. Establishing partnerships with fishermen and transferring acquired knowledge and new technologies to the fishing industry will be priorities for the duration of the program.

3.2 BIOLOGICAL OCEANOGRAPHY DIVISION

The Biological Oceanography Division (BOD) pursues and undertakes research projects aimed at developing a better understanding of biological production systems (primary and secondary production), since these are the very basis of the food chain in the marine environment. The work of the Division deals in particular with study of the interrelations between the various biological communities, their variations in time and space at all levels and their relations with the physical and chemical conditions of the environment. The BOD also studies the recruitment processes

of a number of species of fish and invertebrates which play a major ecological role in the coastal and estuarine marine environment.

The specific mandate of the BOD is therefore to develop the basic scientific knowledge needed to ensure the development, assessment and protection of marine resources and their habitat, and to determine the effects of natural (climate and other) and anthropic change (e.g. exploitation of resources, pollution, regulation of freshwater flow, etc.) on biological production systems.

This research is being carried out in the St. Lawrence Estuary and the Gulf of St. Lawrence (including the Saguenay), as well as in the northern waters around Quebec (Hudson Bay and Strait in particular). The work is of direct interest to researchers, managers and users in the following sectors: fisheries, aquaculture, protection and management of environment and marine organisms (especially fish and invertebrate species of commercial importance, as well as marine mammals).

Over the next five years, BOD priorities will include:

- Continuing the study of the problem related to the presence of microtoxic algae (and their effects on organisms and human beings) in the St. Lawrence ecosystem. The objective is to establish the kinetics of phycotoxin transfer in the food chain of the St. Lawrence ecosystem (e.g. blue mussel feeding selectivity, influence of toxins on the survival of fish and crustacean larvae, etc.);

- Pursuing and enhancing the development of recent technologies (e.g. flux cytometry, fluorometry, LIDAR/LASER, telemetry/ remote sensing, etc.) for analyzing the optical characteristics of particles in the water column (e.g. fluorescence, light dispersal, size, etc.), in order to better quantify and monitor primary and secondary production, as well as the transfer of energy through the food chain;

- Further analyzing the distribution of zooplankton and ichthyoplankton communities in the Gulf of St. Lawrence, as well as continuing research on the nutrition, reproduction, and predation of plankton and fish larvae to explain mechanisms that contribute to variations in recruitment;

- Undertaking studies on the effect of climate and environmental changes on primary and secondary production and fish stocks. In particular, BOD wishes to contribute to national and international efforts to determine how far ocean processes can influence climate changes (global warming due to the greenhouse effect) by absorbing CO_2 from the atmosphere and storing it on the seafloor;

- Developing and implementing a multidisciplinary research program for the northern marine waters around Quebec (e.g. Hudson Strait and northern fjords) to get a better understanding of

variations in marine productivity, major trophic relations, species distribution and the potential effects of environmental changes (hydroelectric development) on these sub-Arctic systems;

- Continuing the research to determine whether the primary and secondary levels of the food chain play an active and determining part in the introduction and transport of a number of toxic substances contained in the trophic web of the St. Lawrence.

The pages that follow provide details of how the above-mentioned priorities will be approached through the various research programs planned by the BOD.

3.2.1 Carbon flux and climate

The main objective of the Carbon Flux and Climate Program is to obtain a better understanding of the dynamics of production of organic plankton particles (primary and secondary food source) in marine coastal and estuarine environments. Future work will deal with the following sub-themes: (1) development of new methods of estimating the space/time distribution of biomass and primary production (e.g. LIDAR); (2) application of analysis of individual particles (flux cytometry) to the study of marine plankton dynamics; (3) determination of the physical and chemical factors affecting the productivity and biochemical composition of phytoplanktonic algae; (4) in conjunction with climate studies, determining the ways and means of organic carbon transport in the ocean environment.

For Sub-theme 1, work will be stepped up on the development of a model to calculate primary production using variables that can be measured by an airborne LIDAR. This work will consist in first comparing readings obtained using LIDAR (light, chlorophyll and yellow matter fluorescence and coefficient of extinction) with *in situ* biomass and phytoplankton productivity, then developing one or more usable models to rapidly, efficiently and economically map (compared to using a vessel) distribution of primary production in coastal and estuarine environments. These nearby synoptic distribution maps of primary production are essential to understanding the production process in an ecosystem as active, in terms of hydrodynamics, as that of the St. Lawrence.

For Sub-theme 2, various projects will be undertaken to determine the potential of the cytometric flux approach to studying the dynamics (growth, grazing, sedimentation, etc.) of natural plankton particles according to their size and optical characteristics (e.g. bacteria, phytoplankton and microzooplankton). This method can also be used to characterize the physiological condition of phytoplanktonic algae on an individual basis. We also plan to develop statistical analysis methods to take advantage of the multivariate nature of data generated by flux cytometry. These new statistical methods will enable us to use the cytometric flux parameter as a dynamic rather than a descriptive variable as is currently the case. These studies are essential to understanding the dynamics of primary production of the marine environment, as well as the transfer of this production to higher levels in the trophic web.

It is recognized that nutrients, and in particular nitrogen, are limiting elements for phytoplankton production in the marine environment. They play a major role in the control of primary production. This is why it is important to understand hydrodynamic (upwelling, fronts, tidal mixing, etc.) and physiological processes (e.g. assimilation rate) respectively linked to their contribution to the environment and their use by cells. As part of Sub-theme 3, laboratory and field work to be performed will deal with: the assimilation and regeneration of nutrients in the natural environment; the importance of various nitrogen sources to monitor the physiological condition of algae; and the study of mechanisms by which phytoplankton adapt to combined variations in nutrients, temperature and light.

As well, climate variations caused by humans have been identified as one of the most serious problems currently facing humanity. In particular, accumulation in the atmosphere of CO_2 and other gases producing the greenhouse effect is rapidly leading to significant warming that might have catastrophic results (floods, famines, local climate changes, hurricanes, etc.). It is thought today that atmospheric and oceanic reservoirs of CO_2 are relatively homogeneous and balanced and that the flux of CO_2 in one of the two reservoirs should be reflected directly in the other. Since most of the CO_2 enters the ocean in the form of bicarbonate and bicarbonate ions, the photosynthesis of phytoplankton, by transforming this inorganic carbon into particulate organic matter, would thus take CO_2 directly from the ocean reservoir. This carbon can then be exported from the photic layer to the seafloor where it can be confined more or less indefinitely. Phytoplankton production can thus directly affect the level of CO_2 in the atmosphere. In this context, the fate of this particulate organic matter in the marine environment becomes very important. It is for this reason that Sub-theme 4 focusses on discovering and quantifying the various transport routes of primary production (respiration, excretion, sedimentation, grazing, etc.) and on studying the physical and chemical factors that determine the relative importance of these different routes.

3.2.2 Toxic and harmful algae

A number of species of toxic microalgae developing in blooms in the coastal waters of Canada form a serious threat to public health and the commercial and recreational use of certain marine species, particularly molluscs. This is not a recent problem, but the intensification of mariculture and increased exploitation of wild resources, combined with the recent discovery of new toxic species and the rise in cases of intoxication, have dramatically highlighted our lack of knowledge of this subject. The dynamics of toxic algae production and the kinetics of toxin transfer through the trophic web must therefore become a priority in our research plans.

Over the next five years, the BOD will therefore carry out research projects under the Toxic and Harmful Algae Program dealing with the following subjects: population dynamics and ecophysiology of toxic algae, transport of phycotoxins in the marine trophic web, and transfer of chemicals in the trophic web of the Gulf of St. Lawrence.

Research will be undertaken to verify the hypothesis that the toxic blooms of *Alexandrium*, which contaminate molluscs along the shores of the St. Lawrence Estuary and the Gulf of St. Lawrence, come from the North shore of the Estuary rather than from endemic populations. We also want to develop a predictive model of the dynamics of toxic algae blooms. Work will continue to establish the kinetics of toxin accumulation in the marine bivalves of the St. Lawrence ecosystem (Sub-theme 1).

An attempt will be made to model the physiological behaviour of toxic algae in a controlled ecosystem and then apply the responses of the model to populations in a natural environment. The kinetics of toxin transfers in the marine food chain of the St. Lawrence ecosystem will be studied through laboratory tests and field work. The purpose is to assess the potential impact of toxins on commercially important species of fish and marine mammals (Sub-theme 2).

We will also be studying the production and transfer of DMSP/DMS (dimethyl-sulphonium-propionate/dimethyl-sulfur) in the trophic web of the northeastern part of the Gulf of St. Lawrence. It is known that these chemicals, produced by microalgae, are transmitted to commercial catches of fish (e.g. cod), thus considerably reducing the market value of the fish. These chemicals also contribute to the fixing of inorganic carbon through photosynthesis and calcification and might play an important role in climate variations (Sub-theme 3).

3.2.3 Recruitment and trophic relations

A better understanding of the variability of ecosystems is important because properly managing marine resources depends directly on the extent of knowledge of factors that control fluctuations in the abundance of marine life. But it has recently been suggested that climate changes and other environmental changes caused by human activity (e.g. control of freshwater flow) might considerably increase the amplitude of fluctuations in the abundance and distribution of marine populations, or at least significantly alter the relative abundance of different species in the long term. These possibilities considerably increase the difficulty of tasks and the degree of uncertainty of fisheries managers and environmental policy.

We have therefore set the following general research objectives for the Trophic Relations and Recruitment Program: to describe and characterize the structure of communities of different Gulf sub-ecosystems (defining trophic links); to determine why fluctuations of largely dominant species in each of the sub-regions are linked to one another and identify the factors that control these fluctuations; to understand how the nature of these separate trophic links can lead to different recruitment patterns and assess the possibility of making forecasts; and to determine the sensitivity of these different sub-regions and the Gulf as a whole to natural and/or human-induced environmental change.

To achieve these objectives, we propose to conduct research projects under two sub-themes: the first dealing with the structure of the St. Lawrence ecosystems; and the second, with processes

related to recruitment and the population dynamics of zooplankton, invertebrates and fish in the various sub-regions of the Gulf.

3.2.3.1 Structure of the ecosystems of the Gulf of St. Lawrence

We currently have only a rather rudimentary knowledge of the structure of communities and trophic interactions in the pelagic ecosystem of the Gulf of St. Lawrence. To close this gap, we propose to acquire as much knowledge as possible on abundance and distribution patterns, as well as on the structure (specific composition) of zooplankton and ichthyoplankton communities in each of the sub-regions of the Gulf. Over the coming years, the research program on the structure of ecosystems will deal specifically with the following studies:

Ichthyoplankton communities - Research will be undertaken to define the spawning and nursery areas of major fish species such as cod, redfish, herring, capelin, hake and halibut. The vertical distribution and degree of spatiotemporal coverage of young developmental stages of development of these different species will also be surveyed. Much of this information already exists in databases from previous research and stock assessment programs, but it has never been assembled in a single bank. This bank will be completed through new field sampling projects and the data will then be used to construct usable images of the structure of ichthyoplankton communities in various sub-regions of the Gulf. These data could then be used to test various hypotheses on the number of separate fish stocks in the Gulf and the specific role of the spatiotemporal distribution of ichthyoplankton in recruitment processes.

Zooplankton communities - We propose to compare the specific composition of all plankton in four sub-regions of the Gulf, the Magdalen Shelf, the Jacques Cartier Strait, the Honguedo Strait and the eastern part of Anticosti Island. For the southwestern Gulf, data on plankton will be drawn from samples in a nine-year time series, collected during a mackerel sampling program. Over the coming years, other samples will be taken in the northern part of the Gulf, and researchers from the Fisheries Research Division will complete the database. This new data bank will be used mainly to compare the structure of communities and, in particular, to determine the relative importance of *Calanus* in each of the sub-regions. The new knowledge acquired will enable us to formulate new hypotheses on the influence of environmental change (natural and/or anthropic) on the pelagic ecosystem of different areas of the Gulf.

3.2.3.2 Processes related to the recruitment and dynamics of populations of zooplankton, invertebrates and fish in various sub-regions of the Gulf

Dynamics of the food chain in the Gulf - It is becoming increasingly clear that the northwestern part of the Gulf of St. Lawrence is characterized by high biological productivity. Based on our previous research, we raised the hypothesis of the existence of a relatively simple food chain for the pelagic zone of the northwestern Gulf that would include phytoplankton, the copepod plankton *Calanus finmarchicus* and redfish larvae.

Over the next five years, the specific objectives of the research program on this aspect of the dynamics of the food chain in the Northern Gulf will thus be to: study the vertical and horizontal distribution and covariability of redfish larvae and *Calanus* eggs in the northwestern Gulf; identify the factors that control this distribution; determine the importance of *Calanus* eggs for the growth of redfish larvae compared to other prey; study the relation between the production of phytoplankton and the production of *Calanus* and, in particular, determine the role of microzooplankton as an intermediary between these two compartments of the trophic web; and finally, study the influence of physical processes on these trophic relations in the northern part of the Gulf. A mathematical model representing our knowledge and basic conceptions of the mechanisms involved will be constructed to assist us in formulating our hypotheses quantitatively and will serve as a tool to identify the future orientation of our research. This model could be used, for example, to test the sensitivity of trophic links, observed in the northern part of the Gulf, to environmental change, in particular climate changes and changes that will no doubt be caused by the development of hydroelectric resources on the rivers of the Lower North Shore.

Factors controlling the spawning of zooplankton and invertebrates - Over the next five years, we will attempt to verify the hypothesis that a number of marine organisms, in particular invertebrates, can actively synchronize their spawning with the primary or secondary production cycles in the marine environment. Our approach will combine field and laboratory studies to establish the relation between spawning by various organisms and food production (phytoplankton and zooplankton) in the environment, in relation with hydrodynamic change. Work will be carried out at sites known to support populations of crustaceans, molluscs and echinoderms, e.g. crab in Bonne Bay, Nfld., scallop in Chaleur Bay, shrimp in the Gulf and the Saguenay, sea urchins and other coastal organisms in the St. Lawrence Estuary. Our study will cover the complete reproductive cycle of the organisms studied. Laboratory tests in controlled tanks will be used to verify the specific processes identified in the natural environment. Based on these results, we intend to develop a new model of trophic relations that will help us to better understand inter-annual variations in the recruitment and larval survival of marine organisms.

Role of gelatinous zooplankton - It seems increasingly clear that gelatinous zooplankton (jellyfish and ctenophores) accumulate in large mixed groups in the Gulf of St. Lawrence during the spring and summer. Research in other regions has shown that this gelatinous zooplankton may have a significant impact on recruitment due to the predatory pressure it exerts on fish larvae. Given the potential importance of this group of predators on ichthyoplankton and zooplankton, a separate long-term research program will be set up to quantify the impact of this group of predators on the survival of fish larvae.

3.2.4 Northern Quebec

Marine mammals, avifauna and anadromous fish have always been important factors in the economy of northern native communities around Hudson Bay and the Hudson Strait. Considerable interest has developed recently in local fishing of other marine species (e.g. shrimp, scallop

and Northern cod) which so far have been practically ignored. To ensure sustainable and profitable exploitation of these resources, careful monitoring and management of exploitable stocks and their habitat are essential. This requires a good understanding of the basic ecology of fished populations, as well as of the environmental processes (e.g. primary and secondary production, hydrodynamics, etc.) that govern their abundance in the northern ecosystem. To date, few valid quantitative studies have been carried out on the ecosystems around Quebec (James, Hudson and Ungava Bays, and the Hudson Strait).

This renewed interest in the exploitation of northern marine resources does, however, coincide with the development of ever-growing apprehension about the various environmental menaces currently threatening the northern marine ecosystem. In particular, hydroelectric development of a number of rivers, which will alter the transport cycles of freshwater and terrigenous matter, and also put mercury back into suspension. There is also growing concern about the possibility that global warming produced by the greenhouse effect might lead to major changes in the northern marine environment. Global warming might result in major changes in the flow of fresh water in the huge reservoir made up of the watersheds that flow into Hudson Bay and in a direct warming of the sea itself. The fact that the Hudson Strait is a subarctic system which contains many marine species near the northern or southern boundaries of their range leads us to think that many populations could be particularly sensitive to even relatively small changes in water temperature. The recent detection of pesticides, polychlorinated biphenyls (PCBs), cadmium and a wide variety of other industrial contaminants in northern fauna and habitat is another cause for concern. All this contamination of the northern trophic web is troubling, since much of the food of northern residents comes from the sea.

Faced with all these potential threats, there is thus a real need to closely monitor and study the northern environment. The long-term effects of changes in the freshwater discharge pattern and the introduction of toxic chemicals into the James and Hudson bays have long been debated and studied. Observation of these effects in estuaries and adjacent coastal waters is increasingly common. However, the potential effect on Hudson Bay, Hudson Strait and the Labrador coast as a whole is still a matter for conjecture and speculation.

On behalf of the Department of Fisheries and Oceans and its clients (e.g. Cree Indians, Inuit, Hydro-Quebec), the Quebec Region is mandated to acquire the basic scientific knowledge needed to support the development, assessment and protection of marine resources (fish, invertebrates and marine mammals) in the northern waters bordering Quebec (James, Hudson and Ungava Bays and the Hudson Strait). To fulfil this general mandate, a workshop on the status of Quebec's northern waters, in particular the Hudson Strait, was organized by the Quebec Region and scientists from various research institutions in November 1989. The workshop stressed the fact that we needed additional data, particularly on the northern part of Hudson Bay and the Hudson Strait, to be in a position to assess the impact of the above-mentioned phenomena. It is for this reason that the Steering Committee for the workshop recommended undertaking intensive research on the Hudson Strait as quickly as possible, as this is the region judged to be

the most important for the productivity of the northern ecosystem under consideration. It is also the region which should feel to a greater extent the combined effect of climate (e.g. global warming) or anthropic changes (e.g. regulation of freshwater flow).

Thus, over the next five years, BOD intends to take the lead in developing, planning and carrying out a multidisciplinary research program on the Hudson Strait, as recommended in the report from the Steering Committee of the Hudson Strait Workshop.

3.2.5 St. Lawrence Action Plan

The dramatic decline of the beluga population in the St. Lawrence Estuary and the Gulf of St. Lawrence is a pressing question for the DFO. Among the hypotheses raised to explain this decline is that of an increase in chemical contaminants in the habitat of this species. It is true that contaminants travel through the trophic web to the beluga and then accumulate due to the high metabolism rate, longevity, limited somatic growth and the large amount of fatty tissue in these mammals. The current state of our knowledge gives us only a partial idea of the level and extent of contamination in the beluga habitat (St. Lawrence Estuary and Gulf) as well as of the nature of major contaminants and the mechanisms that control their dynamics. The basic issue of the presence of contaminants in the trophic web leading to the beluga is therefore of pressing importance. Accordingly, we must give priority to trying to find an answer to this before going on to other more complex studies, as was so justly pointed out in the report of the special DFO committee on the St. Lawrence Action Plan (SLAP).

It is recognized that contaminants are present both in sediments and in the water column. They may thus enter the trophic web from two sources: sediments (e.g. sediments → benthos → worms → groundfish); and the water column (e.g. water column→ plankton → euphausids → pelagic fish). The water column is very important for the transport of contaminants, while sediments act as a reservoir. The water column reflects recent trends, while historical trends are recorded in sediments. Organisms in the water column also concentrate many hydrophilic and lipophilic organic contaminants such as hydrocarbons and polychlorinated biphenyls (PCBs). This is particularly true for northern and cold temperate waters, where phytoplankton and zooplankton are rich in fats. It is therefore just as important to determine contaminant levels in the water column as in sediments. Unfortunately, in the case of the St. Lawrence, we know very little about the organic compound content of sediments, and even less about the water column.

This is why the Biological Oceanography Division and the Chemical Oceanography and Contaminants Division have decided to join forces in a research project to verify the hypothesis that the primary and secondary levels of the trophic web (bacteria/phytoplankton + zooplankton) play an active and determining role in the introduction and transport of a number of toxic substances in the trophic web of the St. Lawrence Estuary. This project, which began in 1990-1991, will continue and intensify over the next five years.

3.3 AQUACULTURE, MARINE MAMMALS AND PARASITOLOGY DIVISION

The mandate of the Aquaculture, Marine Mammals and Parasitology Division (AMPD) comprises three aspects: to conduct basic research in order to develop marine aquaculture in Quebec; to carry out studies on the marine mammals of the St. Lawrence Estuary, the Gulf of St. Lawrence and Northern Quebec; and finally, through the Centre of Disciplinary Expertise for Parasitology, which is part of the Division, to conduct research on parasites of commercially important marine fish and marine mammals.

The Division's aquaculture activities reflect the DFO's Aquaculture Strategy as well as a federal-provincial agreement with the *ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ)*. These activities are carried out in co-operation with universities, community colleges, industry representatives and various government agencies. In addition to its research function, the Division advises the Regional Directorate regarding applications for the introduction and/or transfer of cultured stocks, and is responsible for managing the inspection of aquaculture facilities under the Fish Health Protection Regulations.

3.3.1 Aquaculture research

Aquaculture is one of the possibilities for growth and diversification available to maritime regions and the fishing industry in particular. Profitable development in this area will enhance economic activity, provide new long-term jobs, increase and diversify production and open new markets. The advantages of aquaculture have become more apparent in light of such factors as the current crisis affecting the industry and the attainment of catch quotas. This trend can be observed worldwide, and the development of aquaculture has proved profitable in many countries.

Marine species currently farmed in Quebec are blue mussel and Atlantic salmon. Producers receive government support aimed mainly at consolidating companies, because any possibility of expansion is limited for the moment. The contribution of aquaculture to the development of the fishing industry should thus take the form of farming other marine species. The scientific research required to achieve this objective is one of the initiatives announced by the DFO in its *Aquaculture Strategy for the 1990s*.

The species chosen for farming by the AMPD, Atlantic cod (*Gadus morhua*) and snow crab (*Chionoecetes opilio*), are important for Quebec and all of Eastern Canada. Cod was chosen because of its strong growth potential and great tolerance of farming conditions, and snow crab for its commercial value and its adaptability to cold water. The industry has also expressed interest in farming these two species.

The approach favoured involves developing techniques for the stabulation (to keep alive) and to increase the weight of individuals caught in order to contribute to augmenting the value of

landings and to be able to better control their marketing. The main interest of this approach is in its potential short-term impact. In the longer term, the AMPD will consider the development of farming techniques such as reproduction and larval production.

Over the next five years, the Division thus plans to:

- Pursue its research program on farming Atlantic cod and oversee Research and Development initiatives aimed at identifying the most profitable avenues for industrial farming of this species;

- Undertake a research program on the farming of snow crab that would eventually allow to keep and increase the weight of part of the landings for future marketing.

3.3.1.1 Farming Atlantic cod

The industrial farming scenario envisaged for the moment involves obtaining small cod caught by traditional fishing methods, placing them in captivity (most likely in floating enclosures), feeding them a diet based on fish-plant residue and underutilized fish, and then marketing them as a high-quality product when the market is most favourable.

Work to date by the AMPD has dealt with the tolerance of cod for low salinities, physiological reactions in situations of hypoxia, vulnerability to various pathologies, the detection of metabolic stress indicators and growth performance under different temperatures and rations. This last aspect was examined in a study on the enzyme metabolism of synthetic muscular proteins.

The results obtained to date indicate, for example, that cod tolerate salinities as low as 7 g/L (ppm) and dissolved oxygen concentrations as low as 2 to 3 mg/L. Placed in ideal conditions (feeding at will, 10 °C), some individuals may grow 60% to 100% in less than two months. We did, however, observe hierarchy problems that could inhibit growth in individuals. Except for a short period following capture at sea, cod proved to be highly resistant to stress and disease throughout all our tests.

This program will continue over the next five years using two different but interrelated approaches. The research team will carry out projects on certain biological problems. At the same time, the Division will carry out tests with the industry on the biological, technical and economic feasibility of certain aspects of the enterprise scenario.

The first research project will test the hypothesis that farming cod at intermediate salinities (12 g/L), close to the iso-osmotic point of the fish, causes a decrease in the basal metabolism rate, resulting in energy savings that can be invested in growth. As a corollary, we postulate that this decrease in basal metabolism will also result in increased resistance to hypoxia and stress.

The current project on the enzyme metabolism of protein synthesis will end in 1992. In addition to seeking to identify the enzymes best correlated with cod growth rate and potential, this project provides information on the growth rate and food conversion rate based on the temperature and the ration.

A new project will attempt to elucidate the mechanisms involved in the hierarchy phenomenon we have observed. The objective is to develop strategies that will allow the maximum number of farmed fish to attain their growth potential. We will examine the effect of density on maintenance of this hierarchy, the importance of selection by size, and the food distribution tactics.

In co-operation with the industry, we will be testing various feed formulas developed using ingredients that are easily obtainable and cheap enough to make increasing cod weight a profitable operation. Among the areas examined will be the usefulness of fish-plant residues and the use of species of little commercial value.

Various methods of supplying small cod will also be tested to identify the most efficient and the most economical. We will be running small-scale tests of techniques to increase fish size and methods in floating enclosures. These tests will serve to determine the profitability threshold of the proposed industrial scenario and, if operations are successful, will enable us to transfer the technology to industry by the end of this research plan.

3.3.1.2 Farming snow crab

The research program on snow crab is aimed at developing farming methods that will enable us to enhance the value of part of the commercial catch. Initially, we will examine the possibility of keeping and increasing the weight of "white" (post-moult) crab. In commercial fishing operations, this crab is caught shortly after moulting. Its meat yield is low, however, and if it constitutes too large a proportion of the catch, the season on this species is normally closed. White crabs thrown back into the sea are also subject to a certain degree of mortality, which causes a considerable loss of resources.

A second approach which is of interest to the industry involves the recovery, from crab landings, of individuals that still have growth potential, inducing them to moult and increasing their weight until a quality acceptable to the market is reached.

Within the framework of the projects which will be set up over the coming years, we will first be looking at the tolerance limits of snow crab to farming conditions . Among the areas studied will be the effect of temperature and salinity on survival and growth.

In order to develop an adequate and sufficiently inexpensive diet, we must determine the nutritional requirements of this species. The feed thus developed will be tested by measuring appetency and efficiency (assimilation and yield rates).

Other projects will deal with moulting and growth. Through monitoring the development of moulting stages, we will attempt to identify a simple, efficient criterion enabling us to make short-term predictions of the moment of exuviation (casting off the old shell). This tool will enable us to reduce the risks of cannibalism on moulting crabs, which might then be isolated. We also plan tests to monitor and induce moulting for handling purposes for farming, and we will be examining the duration and possibility of accelerating the post-moulting state to marketable size in order to reduce the farming time needed.

3.3.2 Marine mammals

Research projects on marine mammals deal mainly with the following: population dynamics; reproduction and mortality; assessment; distribution; migration and behaviour of populations; diet, feeding and energy transfers; vocal behaviour and communication; studies on contaminants and toxicity; studies on parasites; diseases and their manifestations. Research on most of these aspects is generally interrelated.

We are currently seeing a growing popularity in the use of marine mammal populations as an education and tourist resource and as a component of a healthy marine ecosystem. The DFO must define its policy on by-catches of marine mammals in fishing gear accordingly by collecting data, surveying and monitoring the problem more closely.

Paralleling the interest in marine life, the number of tourist cruises to observe whales is increasing. Observers need scientific data in layman's language on the distribution and movement of whales. It will also be important to set up refuges for whales to protect them from this influx of observers.

The problem of beached whales is of considerable interest to the public, and the DFO must therefore tighten its policy on beaching, particularly in cases where the beached specimens are alive.

The various points raised above orient us towards studies of the behaviour and health of marine mammals, thus minimizing the importance of population dynamics.

The decrease in commercial fishing catches is causing serious problems for fishermen, who blame seals of being the main cause of this problem. We must therefore be able to calculate and specify whether seals really have a harmful effect on commercial fish stocks. This could be assessed by studies on the energy sources of seal, its feeding habits and the size of populations.

As for research on large whales, we will be looking at the effects of their feeding on fisheries. Conversely, we would also like to know the effect of fishing on these mammals, particularly with respect to the even greater potential development of fisheries for invertebrates and species of underutilized pelagic fish in the Gulf. Work will be carried out on the abundance, distribution and movement of large whales in the St. Lawrence Estuary and the Gulf of St. Lawrence. An attempt will be made to estimate population biomass, dynamics and trends and to identify the species consumed by them. Research will be undertaken to shed light on the relations between the large whale communities in the Gulf and populations found in the northwestern Atlantic.

Sea missions will be made to inventory these whales (number, distribution, movements). We will also take the opportunity to carry out studies on their behaviour, determine the relations between species, take samples by biopsy to allow us to analyse genetic composition and radio-tag migrating whales in order to follow their movements.

In conjunction with the St. Lawrence Action Plan and Interdepartmental Action Plan to Favour the Survival of the St. Lawrence Beluga Whale, we will continue to monitor the population of this endangered species to determine whether it is growing or regressing and if there are factors limiting its growth, and define these factors if appropriate. The effects of contaminants on the birth and death rates will also be studied. If these effects prove significant, the mechanisms by which they act and the means to remedy the situation will be determined. We will also be looking at the genetic variability (DNA analysis) of individuals and its effects on the viability of the beluga population of the St. Lawrence.

We will also study porpoises and Atlantic white-sided dolphins to learn more about their population dynamics and abundance, as well as to determine the effects of by-catches on the viability of populations of these species in the St. Lawrence.

Studies on the three species of seal living in or using the Gulf will continue in coming years. These are the grey seal, harp seal and harbour seal.

Grey seal, with an estimated population of 100,000 individuals on the Canadian Atlantic coast, is the main host of sealworm (*Pseudoterranova decipiens*). Research will be carried out to estimate the quantity of commercial fish eaten by this seal and to determine the areas where it prefers to feed. We will also estimate the size of the grey seal population in the Gulf, studying the role played by this species in the dynamics of the sealworm and determining seasonal changes in its rate of infection by this parasite. Relations between Gulf herds and those of Sable Island will be investigated.

The harbour seal, with a much smaller population than that of grey seal (approximately 12,700 in Eastern Canada based on 1973 data), is also a host of the sealworm. This species of seal is a permanent resident of the St. Lawrence Estuary and the Gulf of St. Lawrence. We will be seeking

to determine if it is as contaminated as the beluga of the St. Lawrence and, if so, we will examine specimens to determine the pathological effects caused by contaminants. Necropsies will be carried out on beached specimens to check for the presence of pathological changes. An inventory will be made of this species in the St. Lawrence and the interactions between harbour seal and grey seal will be studied, particularly with respect to competition for food. Studies will be carried out on the movements of harbour seal in relation to the Saguenay Marine Park.

Similarly, research will be done on the number and population dynamics of harp seals. Interactions of this seal with commercial fish and crustacean species will be studied. We will also be looking at the effects of by-catches of seals in fish nets on seal population dynamics.

For the belugas of Northern Quebec, research will focus more on movement and migration studies, including marking projects using either tags or satellite beepers. A task force made up of members of the Central & Arctic Region and the Quebec Region will develop a five-year research plan on belugas. Although management of stocks depends to a great extent on the population dynamics and basic biology of monodontids (these areas are well researched), little is known about the differentiation of northern beluga stocks, thus limiting our ability to adequately manage them.

3.3.3 Parasitology

A major component of the parasitology research program of the AMPD will be devoted to studies of the life cycle of the sealworm (*Pseudoterranova decipiens*) in order to obtain a better understanding of it. Working with other DFO researchers in the Atlantic region, we will be studying the fundamental biology and life cycle of *P. decipiens*, with emphasis on initial larval development and identification of the invertebrates that serve as intermediate hosts to this parasite. The ultimate objective is to determine more precisely how this parasite is transmitted from seals to fish.

Laboratory studies will place *P. decipiens* larvae together with invertebrates to study the infection process. The eggs and larvae of the parasite will also be studied under controlled conditions. Additional experiments will be performed to determine whether small fish can be directly infected, i.e. without use of an intermediate host (an invertebrate). Field work (sampling and observations) will also be needed in areas where seals are severely infected by this parasite (Sable Island, Anticosti Island and the Îles-de-la-Madeleine).

A general survey of the parasites present in one or more economically important fish species will be undertaken, in collaboration with researchers from the Fisheries Research Division. This study will provide basic data on the parasite fauna of these fish and the pathogenic effects that parasites engender in their hosts. This information will be useful to fisheries management scientists in determining the population structures and migratory patterns of these species. This

type of survey will also have other advantages such as offering valuable basic data to deal with the admissibility and marketing of fish products.

Since capelin and smelt are the preferred food of cod and are also eaten by seals, we will be studying the prevalence and intensity of infection by nematode parasites (sealworm, whale worm and other Ascaridoidea) in these two species. This could be useful in understanding the biology of these parasites and their transmission to seals and whales. The results of this study could also serve to identify areas or stocks that could be priorities for fishing because of their low infection rates.

A longer-term project (10-15 years) on parasites of seals and whales in the Canadian Atlantic will be undertaken by MLI pathologists in co-operation with other research centres. The overall objective of this project will be to obtain a detailed understanding of the parasites of these marine mammals, their geographical distributions and their possible roles as factors limiting the growth of marine mammal populations. Initial efforts will focus on common porpoise, grey seals and harbour seals. The beached carcasses of large and small whales will be also examined with the collaboration of research institutions which may be involved in the long-term project. We will be looking particularly at lungworms (Nematoda: Metastrongyloidea) which cause pulmonary lesions which appear to interfere with the breathing capacity of marine mammals when they dive.

3.4 FISH HABITAT DIVISION

3.4.1 Habitat research and evaluation

The activities of the Fish Habitat Division (FHD) are governed by the *Policy for the Management of Fish Habitat*, adopted by the government in October 1986. This policy is aimed at obtaining a net gain in habitat for Canada's fisheries resources. It is based on a plan geared toward the protection, conservation, restoration, and enhancement of fish habitats, as well as toward strategies for the implementation of these elements. Since its adoption, the DFO has been working to implement the various aspects of these strategies through a series of national and regional activities coordinated by national committees.

In this context, the Fish Habitat Division coordinates the scientific aspects of all questions dealing with fish habitats in the RSBQ. In the Science Sector, the activities dictated by this policy fall into two categories: scientific research on habitat; and habitat evaluation. The habitat evaluation program provides scientific advice to managers on fish habitat, while the scientific research program advances knowledge on habitats to support the scientific basis of our advice.

The scientific research program is geared to the ecological modelling of habitat in order to gain knowledge of the environmental and human factors that determine the features of these habitats. We intend to develop models enabling us to understand and predict the changes which would

occur in habitats subjected to perturbations. Particular attention will be paid to the production capacity, given the importance of this parameter in the *Policy for the Management of Fish Habitat*. The development of advanced modelling techniques is an integral part of the program. Depending on the possibilities arising in the coming years, we plan on increasing our efforts to recognize habitat quality indicators and to model their cumulative effects on habitats.

The habitat evaluation program provides scientific advice to fish habitat managers. Preparation of these reports varies with the nature and scope of the questions, as well as with our knowledge of them. The reports are written following the examination of available information, a literature review, and consultation with experts. Study projects are also carried out in the short and medium term to respond to the more immediate needs of managers.

The area covered includes the marine environments within the responsibility of the Quebec Region: St. Lawrence Estuary and Gulf of St. Lawrence, Chaleur Bay , Saguenay River and Northern Quebec. Included among the ecotones of the marine environment are sandbars, river estuaries, and lagoons. Certain freshwater areas, such as the St. Lawrence River corridor, the salmon rivers of the Quebec North Shore, or the lakes of the Canadian Shield can be studied under special programs such as the St. Lawrence Action Plan.

The paragraphs that follow briefly describe the main projects planned by the FHD to implement its programs. These projects will deal with habitat quality, habitat quantity, and habitat restoration and development.

The first project involves modelling flows of energy and material in planktonic trophic webs. This project will lead to the development of diagnostic models of carbon and nitrogen circulation in freshwater planktonic trophic webs, ice algae communities, and the estuarine environment. These models will enable us to understand the process of habitat production and better quantify the biological parameters in predictive models of marine ecosystems. This project will also allow us to collect information on the production capacity of several types of habitat.

Another project is planned to determine the impact of random physical disturbances on the plankton ecosystem. This will be done by studying interactions between the biological factors and these perturbations in circulation (eddies, internal waves, current meanders, etc.). Little is known about these transitory phenomena, mainly because of the difficulty of sampling them. Physical and biological interactions will be analyzed in two systems, one coastal and one oceanic, where the bottom topography regularly causes the development of transitory disturbances. This study will enable us to better link the physical variability of the marine environment to its fishery capacity and will be useful for understanding the effects of human factors on habitat processes.

We intend to develop models for assessing the quality of coastal habitats. We will first examine the possibility of basing these models on the concept developed by Sheldon, who described a logarithmic relation between organism size and the biomass present. The size spectrum will be

examined in various habitats and will be used to develop models to assess habitat capacity and habitat quality indicators. The first step will involve establishing Sheldon relations in various habitats and using them to assess the quality of these ichthyoplankton habitats.

The Division is also concerned with the impact of discharge at sea on the coastal habitat. Among the questions being examined are the transport and introduction of exotic species from the ballast water of ships. Vessels from all countries currently discharge their ballast waters in the St. Lawrence River system. Although there is little information on this practice, it might constitute a danger for Atlantic marine habitats when ballast waters contain foreign marine organisms. Research projects have recently been undertaken to document the practice of discharging ballast in the Gulf and to assess the risk of introducing organisms. We will also be studying the risk of introducing chemical contaminants and exotic species into the Grande Entrée Lagoon of the Îles-de-la-Madeleine. These projects will continue over the coming years.

We will be continuing our study of the effects of discharged dredged sediment on coastal habitats and resources. We will complete the dispersion model of dredged sediments in order to increase our ability to predict particle transport. This model will enable managers to make more informed discharge site choices, thus providing more protection for habitats and resources.

Under the St. Lawrence Action Plan, the Division and the St. Lawrence Centre (SLC) have undertaken a project to test the validity and relevance of various indicators of habitat quality in the St. Lawrence with respect to chemical contamination. These include biochemical and histological indicators as well as parasitism and deformity rates. This project will continue for the next few years.

Work will begin on a geographic information system for fish habitats containing all the physical, chemical, and biological information on habitats which might be useful for application of the *Policy for the Management of Fish Habitat*. This system of oceanographic information will be used for three purposes: 1) making research data on habitats available for the preparation of reports to advise managers; 2) permitting better integration of data and promoting the development of an integrated research program on habitat; and 3) providing quick access, in the event of chemical spills in the marine environment, to information essential for identifying affected or vulnerable habitats in order to properly direct protection and restoration efforts.

We will be conducting several projects aimed at quantifying the success of restoration and development attempts. We will continue to study the evolution of biological communities and the physical characteristics of artificial islands created by dredging sediments in the Grande Entrée Lagoon. The biophysical characteristics of the Havre-aux-Basques Lagoon have also recently been studied. When the lagoon is reopened, we intend to closely monitor changes in the physical, chemical, and biological components of the system. In particular, the study of production capacity will enable us to quantify the success of this restoration.

We will be consolidating the environmental assessment program in order to provide scientific advice necessary for the sound management of fish habitats. The program will call upon a number of methods to produce scientific reports. These methods will include consulting with RSBQ experts, reviewing and interpreting the data available in the literature, acquiring knowledge through the Division's research projects as well as through all RSBQ programs (if needed, we will call upon experts from outside the MLI), conducting applied research, and consulting the information system on fish habitats. This program will play an increasingly important role over the coming years due to the Department's greater involvement in environmental matters. In the short term, major issues include the environmental assessment of hydroelectric development on the Grande rivière de la Baleine and the Sainte-Marguerite and Ashuapmushuane Rivers. We will also study the cumulative effects of these developments on the marine environment.

3.4.2 Long-Range Transport of Atmospheric Pollutants

In view of the scope of the problem of acid precipitation first realized in the early 1980s, the federal government set up a program to study the Long-Range Transport of Atmospheric Pollutants (LRTAP). This Canada-wide program is conducted by several departments, including the Department of Fisheries and Oceans. The DFO's role is to provide the scientific information needed to assess the impact of atmospheric pollutants on aquatic environments.

The LRTAP V program, which covers a period of 6 years, was started in 1991-92. The DFO's objectives are to:

- Assess the impact of acidification on fish populations;

- Study the repercussions of spring acid shock, a particularly severe problem in Quebec;

- Determine the history and development of the effects of atmospheric pollutants on aquatic environments; and

- Participate in the National Biomonitoring Program aimed at monitoring the recovery of biological systems following emission-control programs.

Various projects will be carried out to achieve these objectives. We will continue to participate in the National Biomonitoring Program in lakes in La Mauricie National Park and in the salmon rivers of the north shore of the St. Lawrence River. The objective of this program, implemented in 1987, is to carry out long-term monitoring of ecological communities and ecosystem recovery following the implementation of Canadian acid-emission control programs.

We will be completing our research on the paleoecology of the acidification of lakes in the Precambrian Shield to determine the changes in deposition of acid rain and heavy metal pollutants in Eastern Canadian aquatic ecosystems over the last 200 years.

We will continue with our study on the survival of juvenile brook trout exposed to acidification. In many lakes where this species is found, the study of age structures shows low juvenile survival rates. The literature reports no increased mortality among eggs and fry in acidic lakes, so the hypothesis was put forth that first-year juveniles cannot accumulate sufficient energy to live through the winter. Laboratory and field work is now being carried out in the *Réserve faunique des Laurentides* area to test this hypothesis.

3.5 SCIENTIFIC COMPUTING DIVISION

In 1984, the Fisheries Research Division and the Biological Oceanography Division acquired separate computer resources to support their stock assessment and research activities. In 1990, the Regional Informatics Master Plan identified the need to combine the computer-related human resources of the Biological Sciences Branch in order to increase the efficiency of this service and ensure the structured and congruous development of information-system operations. The Scientific Computing Division (SCD) was formed in April 1991, and its mandate is to support computer-related activities at the Biological Sciences Branch to meet the needs and priorities of the scientific programs. This support will be based on the financial resources and personnel allocated to the SCD over the coming years.

The activities of the SCD may be divided into the following areas: microcomputer support and software; development of data acquisition, management, validation, processing, analysis, presentation, access and archival systems; support and advice to clients on the use of computer technology; technology integration from a hardware and software perspective; introduction of methods and standards to support these activities; training SCD personnel and clients in the use of computer tools; coordination of computer security; management of the SCD.

In the short term, the SCD will concentrate its efforts on priority projects such as modelling and structuring the oceanographic data of the Grande rivière de la Baleine area and setting up an oceanography database on Oracle. It will work on: finalizing the basic architecture of data from commercial sampling, catches and fishing efforts, as well as from the Observer Program (17 species); reorganizing the systems for analyzing and processing these data; creating a database for abundance surveys of groundfish and shrimp and integrating it into the commercial sampling database project; converting Index Fishermen Program data from the Q & R system to Oracle; rendering historical data accessible from NAFO (North Atlantic Fisheries Organization) on the VAX system.

Among the major projects to be carried out by the SCD over the next five years are the implementation of an integrated data management system on fisheries research (stock assessment), completion of the oceanography database and that of the geomatic project on fish habitat.

PHYSICAL AND CHEMICAL SCIENCES BRANCH

The Physical and Chemical Sciences Branch (PCSB) is responsible for developing a better understanding of the physical and chemical nature of the St. Lawrence Estuary and of the Gulf of St. Lawrence, the northern waters of James and Hudson Bays, Foxe Basin and the Hudson Strait. It must also enhance knowledge on toxicology. The Branch's main objective is to identify and study the physical and chemical processes of the marine environment and their effects on ecosystems. This knowledge is essential for the sound management of renewable and non-renewable marine resources, for understanding the impact of marine pollution and other human activities such as hydroelectric development, and for protecting and conserving the marine environment for future generations. The PCSB is also responsible for supplying the entire Regional Science Branch - Quebec Region with physical and chemical calibration, measurement and analysis services. It also assists the Gulf Region in physical and chemical oceanography matters.

The Physical and Chemical Sciences Branch consists of two divisions: Physical Oceanography; and Chemical Oceanography and Contaminants (FIGURE 1 and FIGURE 6). In addition to the DFO Science Sector and DFO management, the PCSB's main clients include its partners from the federal government (e.g. Environment Canada, Transport Canada, Energy, Mines and Resources), the provincial government (e.g. *ministère de l'Environnement du Québec - MENVIQ*), the universities (e.g. *INRS - Océanologie, Université du Québec à Rimouski - UQAR*, McGill University), the fishing and technology industries, foreign collaborators (e.g. *Institut français de recherche pour l'exploitation de la mer - IFREMER* and *Centre national de la recherche scientifique - CNRS)*, the international scientific community, and organizations from the public or private sector specializing in the marine environment. Research by the Branch is communicated regionally and nationally as well as internationally.

National and international research collaboration - The research program described above cannot be carried out by the Physical and Chemical Sciences Branch alone. It does not have all the necessary resources to conduct certain paleoceanographic studies, for example. Fortunately, the problems of the Gulf of St. Lawrence are of interest to scientists from other government bodies as well as universities, as evidenced by the list of participants in the Symposium on the Gulf of St. Lawrence. Nevertheless, the Physical and Chemical Sciences Branch forms, with the Biological Oceanography Division, the main focal point of oceanographic research on the St. Lawrence System. The PCSB therefore wants to be a primary partner in the development and coordination of overall efforts in this field.

Even if resources were available, the study of the Gulf system should not be done in isolation. It should be done in conjunction with international research on similar coastal systems. This would help keep us competitive and abreast of technical and theoretical advances in this field.

FISCAL YEAR 1992-93
Physical and chemical sciences 39.0 P/Y (Base)

APRIL 1992

DEPARTMENT OF FISHERIES AND OCEANS
REGIONAL SCIENCE BRANCH
QUEBEC REGION

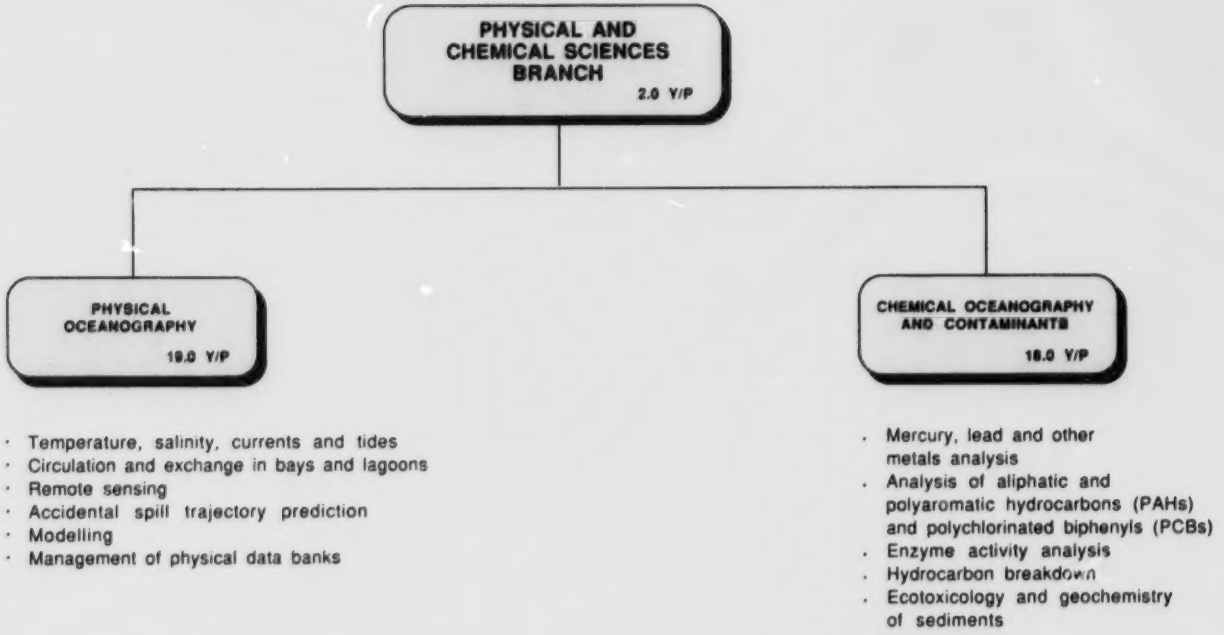
PHYSICAL AND CHEMICAL SCIENCES BRANCH
2.0 Y/P
PHYSICAL OCEANOGRAPHY
19.0 Y/P
CHEMICAL OCEANOGRAPHY AND CONTAMINANTS
18.0 Y/P
· Temperature, salinity, currents and tides
· Circulation and exchange in bays and lagoons
· Remote sensing
· Accidental spill trajectory prediction
· Modelling
· Management of physical data banks
· Mercury, lead and other metals analysis
· Analysis of aliphatic and polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs)
· Enzyme activity analysis
· Hydrocarbon breakdown
· Ecotoxicology and geochemistry of sediments

FIGURE 6 : Fields and areas of activity of the Physical and Chemical Sciences Branch and allocation of personnel.

For example, there are striking similarities between the Gulf of St. Lawrence and the North Sea. The southern part of the North Sea, which is shallow with sand and gravel sediments and high productivity, resembles the Magdalen Shelf. The northern part of the North Sea, dominated by the Norwegian Channel which is 400-600 m deep and follows the south coast of Norway, crossing the edge of the continental shelf to join the Norwegian Sea, is similar to the deeper parts of the Gulf. The upper part of the Norwegian Channel lies in Skagerrak Sound, where fresh water from the Baltic flows into the North Sea. It closely resembles the upper part of the Laurentian Channel in the St. Lawrence Lower Estuary. In the North Sea as well as in the Gulf, modern sedimentation takes place in basins or channels. Water circulation patterns are similar in both seas: in a counter-clockwise direction in the shallower parts, while currents are stratified in channels. The North Sea and the Atlantic are mainly linked by the Norway-Shetland-Scotland sector and the English Channel, which corresponds with the Cabot Strait and the Strait of Belle Isle in the Gulf. In light of this, the Physical and Chemical Sciences Branch should cultivate close relations with European scientists studying the North Sea system.

Canadian scientists studying the Gulf of St. Lawrence have a number of advantages that their European colleagues do not have. Since the Gulf is under the jurisdiction of a single country, it is easier to obtain a concerted research effort than it is for the North Sea. The Gulf is smaller, and this facilitates its study as a comprehensive system. In addition, it is relatively unpolluted compared to the North Sea and may be considered an example of a coastal system that has been maintained in a nearly natural state. There are good reasons to believe that knowledge used in one of these systems might be directly applicable to the other. Solid ties should therefore be established with European scientists .

Within a broader context, the Gulf of St. Lawrence may be seen as the prototype of a temperate-latitude coastal environment, like the Eastern Canadian continental shelf, the North Sea, the Okhotsk Sea and the China Sea. This provides an excellent opportunity for Canadian scientists, particularly those of the Physical and Chemical Sciences Branch, to play a leading role in the study of the oceanography of the marine coastal environment.

4.1 PHYSICAL OCEANOGRAPHY DIVISION

The Physical Oceanography Division (POD) of the Maurice Lamontagne Institute is mandated to study the physical processes and marine circulation in the St. Lawrence Estuary-Gulf system, as well as in the northern waters bordering Quebec. The region most studied, because of its marine resources and its importance for navigation, is the St. Lawrence Estuary-Gulf system. Depending on the resources available, the study of northern environments may become a major component of the Division's activities.

The POD's first priority will be to continue its development and become fully operational by the end of 1992-1993. To achieve this, two positions will be filled during the current year. This will

enable us to arrive at a critical mass of researchers and complete the development of the equipment calibration and maintenance section, as well as that of data processing and archiving. Our collaboration with physical oceanographers from outside organizations such as the *Université du Québec à Rimouski*, the *INRS - Océanologie* and McGill University will be increased in order to maximize the use of these many resources. The development plan should be sustained by a minimum of financial support from the Capital Program. It will, in fact, soon be impossible for the POD to stay at the same level as other Department of Fisheries and Oceans research centres if it cannot, like them, acquire adequate data collection equipment.

The Division has two objectives: 1) completion of current programs (most of these programs will be completed within two or three years); and 2) development of monitoring, analysis and research programs to assist in solving environmental and ecological problems. The latter objective will comprise four components: intensive observation programs in critical regions; long-term monitoring; development of a numerical model of circulation (in collaboration with the Canadian Hydrographic Service Branch and other regional institutions); and setting up a regional database to disseminate information.

The geographical region under the responsibility of the Maurice Lamontagne Institute is large. It includes the St. Lawrence Estuary and the Gulf of St. Lawrence, as well as the northern waters bordering Quebec. DOP's Research on the Estuary and the Gulf of St. Lawrence will be carried out by participating in multidisciplinary and multi-institution campaigns, co-operating in the development of a numerical model of the circulation in the Estuary and the Gulf, and participating in the St. Lawrence Action Plan and the Joint Global Ocean Flux Studies Program (JGOFS). In northern regions, resources such as new personnel, equipment and vessels are essential to continue and intensify our research in these regions. One of the solutions envisaged is to involve the POD at the national level, in the *Fisheries in a Changing Climate Program.*

4.1.1 Estuary and Gulf of St. Lawrence

Because of its dimensions, the St. Lawrence Estuary-Gulf system is the only coastal system of its kind in the world. The physical phenomena observed in the Estuary are more similar to the phenomena observed on continental shelves than in "classical" estuaries. The Gulf, on the other hand, is more like a marginal sea than a "classical" gulf or a large estuary. The waters of the three main layers of the system come from three different sources: fresh water from rivers (especially the St. Lawrence and the Saguenay), the Strait of Belle Isle (the intermediate layer) and the Cabot Strait (the deep layer). The latter two layers are found up to the mouth of the Saguenay, while the influence of fresh water from the St. Lawrence River is felt right to the northeastern coast of the United States.

Over the past few years, research in physical oceanography has been primarily focussed on the general circulation of the St. Lawrence Estuary - Gulf system. As the complexity of this system became more obvious, scientists began to look at "regional" problems related mainly to

environmental concerns or fisheries such as upwelling, fronts, mixing processes in larval retention areas and pollutant transport. Knowledge gains oblige us to study in more detail more limited regions in order to analyze local processes and then return to the larger scale to obtain a better understanding of the interactions between the different length scales of the biological, physical and geochemical processes. We shall be increasingly required to work with multidisciplinary and inter-institutional groups.

Over the coming years, the Physical Oceanography Division will undertake and pursue the research projects described below.

4.1.1.1 Coastal processes

Hydrodynamic studies on the Jacques Cartier Strait are aimed at studying the influence of freshwater flow (future hydroelectric harnessing of the rivers of the Quebec North Shore) on the circulation and the mixing of waters in the northern part of the Gulf, as well as the influence of circulation on the distribution and transport of shrimp larvae in the region. This study started with the measurement of current and water level over a one-year period (1987-1988). Measurement in more limited areas of the Strait for two six-month periods, one before and one after the main coverage, completed the sampling program. These were the first winter current measurements ever taken in the Gulf. Cross spectral analyses between physical parameters and larvae concentration measurements have shown that, in the surface layer, biological time scales are shorter than physical time scales. Redistribution of larvae by physical processes seems much more efficient in the Jacques Cartier Strait than in the northwestern Gulf. Much still remains to be done, however; we must for example analyze winter data, complete the study of tidal propagation in the entire region and analyze thermistor chain data. This latter analysis will enable us to establish relations between upwelling and mixing zones with satellite data of sea-surface temperature.

A major program deals with the problem of Lagrangian transport of larvae in lagoons and bays. The objective is to study water circulation and retention mechanisms to determine their impact on aquaculture sites. Measurement campaigns in the Baie de Caraquet (1987 and 1988) in New Brunswick, in the Grande Entrée Lagoon of the Îles-de-la-Madeleine (1989 and 1990), and in the Baie de Gaspé (1990) will enable us to determine the distribution process as well as that of larvae and phytoplankton transport both within and outside these bays and lagoons. Preliminary results have already shown that tide is the most important agent in the Baie de Caraquet, while wind is the most important agent in the Grande Entrée Lagoon. Larvae in the Baie de Caraquet seem more likely to spread outside the bay once they reach maturity. In the future, we should improve our measurement systems (drifting buoys and other sampling systems) in order to be able to choose the aquaculture sites most likely to be biologically and economically profitable. This project on the dynamics in bays and lagoons will be carried out in co-operation with the *Université du Québec à Rimouski* and the Gulf Region (DFO).

Another major program deals with the multidisciplinary study of medium-scale interactions between the physical, biological and geochemical processes in the Rimouski region. These interactions must be properly understood if we are to determine the carbon production and transformation processes on various spatial scales (a priority of the international Joint Global Ocean Flux Studies program - JGOFS). Regionally, we want to study the distribution and transport of passive contaminants (pollutants, red tides, etc.) entering the Lower Estuary. Under this program, the Lower Estuary has been divided into three study areas: the head of the Laurentian Channel; the Rimouski Gyre; and the mouth of the St. Lawrence Estuary. Measurements at the head of the Laurentian Channel (1983, 1984, 1987 and 1990), the most dynamic part of the system, will allow us to study the formation of surface waters and the related physical phenomena: upwelling, internal waves and tides, mixing fronts and processes. Measurements taken at the mouth (1990) and in the Rimouski Gyre (1987, 1988, but particularly in 1989 and 1990) will allow us to close the system and assess the impact of external forcing on the area of the gyre. Intensive simultaneous sampling (over time and space) of physical, biological and geochemical parameters will be carried out at this location. To the best of our knowledge, this is the most ambitious multidisciplinary sampling program ever carried out in an estuarine environment.

4.1.1.2 Modelling and monitoring

We will continue to concentrate on the development of a three-dimensional numerical model of tide and circulation of the St. Lawrence Estuary-Gulf system. This will involve working with other regional institutions. The model, coupled with series of regional measurements and a more modest but less costly large-scale monitoring system, will form the basis for our future research on the circulation and transport of passive contaminants throughout the system. This model is essential for understanding both the Gulf of St. Lawrence as a whole and a few more limited but highly complex regions. With scientists from other research centres, we began a three-year project in 1990-91 to develop such a model for the middle and maritime estuary. The project will also involve validating the model using current meters moored for periods of six months. Airborne and satellite measurements will identify frontal zones. These measurements will be validated by simultaneous measurements at sea and may be compared to the model results. The next phase of the project will be to apply the model to the Gulf as a whole.

Quantification of atmospheric forcing is difficult because of the intermittence of the phenomena. This problem will be tackled on two fronts. First, in collaboration with the Atmospheric Environment Service, federal Department of the Environment, Quebec Region, a project has been set up to moor a weather buoy in the northwestern Gulf during the ice-free period, for an initial period of three years, from 1991 to 1994. These measurements will enable us to establish the difference between measurements at sea and extrapolations of land measurements. Current measurements will also be taken around the buoy. This will allow us to assess the response of the water column to local winds. Second, a numerical model of the influence of orography on

surface winds, already under development (Parent, 1990), will enable us to obtain more realistic wind fields based on data from coastal stations.

The observation programs mentioned above are fundamental to the understanding of general circulation. Action has also been taken by the POD with regard to these. Firstly, it has acquired several temperature-salinity probes in order to equip all MLI research teams doing sampling work in the Gulf. Thus a physical database can be built up as biological and chemical data are collected. The two series of data can be correlated, making it easier to estimate variations in water circulation. Secondly, the use of satellite or airborne remote sensing is already quite common. An image processing system has been set up and will become more accessible as auxiliary equipment becomes available. Use of remote sensing as a data acquisition tool is already a part of many projects, and this trend will continue.

4.1.2 Northern environments

Northern environments are a special challenge for scientists in the physical sciences because of the large areas to be explored. Hudson Bay is the largest inland sea in the world. If we combine the area of the Hudson Strait, James and Ungava Bays and Foxe Basin, we obtain an oceanographic unit much too complex for the current resources of the Physical Oceanography group at the Maurice Lamontagne Institute. These regions are characterized by water flowing in from three different sources (Arctic, Atlantic and fresh water) with mixing occurring at various locations (river outlets and the confluence of water masses) and under different conditions. They are also under the influence of seasonal ice coverage which further complicates observation and data interpretation. This makes it desirable to restrict research in these regions to more limited areas.

4.1.2.1 Previous research

Up until now, most of the research in physical oceanography in northern environments was performed in the Kuujjuarapik area. Projects already carried out by Institute personnel were aimed at completing work begun by the Canada Centre for Inland Waters in the late 1970s in order to assess environmental conditions before proceeding with the hydroelectric project on the Grande rivière de la Baleine. The results of these studies, which dealt with water circulation, indicated that currents varied significantly both spatially and temporally in this region during the winter and under ice cover. The analyses performed also showed that variation in atmospheric pressure gradients is probably the principal factor influencing circulation and the form of the freshwater plume of this river. A study on the climate conditions leading to the formation of a huge coastal ice pack in this part of Hudson Bay indicated that wind storms are responsible for the variation in size of the ice pack from year to year. This study also enabled us to develop a methodology for assessing surface currents by modelling ice floe drift. Finally, analysis of meteorological data collected on the ice pack led to an evaluation of the local factors influencing wind measurement at the Kuujjuarapik coastal station.

In addition to this work in Hudson Bay, Division scientists also participated in a sampling campaign to assess the effects of harnessing the La Grande Rivière. This program, undertaken in co-operation with the McGill University Oceanography Institute and the *Société d'énergie de la Baie James*, for their logistic support, allowed us to detect the determining influence of the ice cover on the discharge of the freshwater plume at river mouths. It thus became clear that the plume ended at the edge of the coastal ice pack, where the ice is free and can be moved by the wind.

Scientists also contributed to a current-measurement program in the eastern part of Ungava Bay. These were the first modern circulation measurements in this region. Analysis of the data showed a strong barotropic component in tidal currents, as well as a baroclinic component in the median current. A study of the biological and physical dynamics of a tidal front showed that this frontal zone influenced the distribution of organisms.

4.1.2.2 Future research

As mentioned above, it seems unrealistic to study all of these regions in depth because of their diversity and size. Previous research work has shown that the in-depth study of a well-defined area with specific physical phenomena is just as effective in fulfilling the Department's overall mandate. This is therefore the approach we have chosen for the coming years. We will be focussing on two main areas: the impact of hydroelectric development and the study of the Hudson Strait. These projects will nevertheless require significant logistic support (vessels, helicopters, temporary camps, long-term moorings, etc.). The research planned in Hudson Bay and the Hudson Strait can only be carried out if we have a significant amount of vessel and helicopter time as well as adequate long-term financial support.

The Grande Baleine project - In the area of hydroelectric development, the Physical Oceanography research group should continue work already underway in the Kuujjuarapik area, since the Grande Baleine construction project will be in the forefront in the coming years. In 1989, Hydro-Quebec announced its intention to build a series of three generating stations on the Grande rivière de la Baleine. To do this, it must divert the waters of that river as well as two other smaller rivers to make them flow into Manitounuk Sound. This means not only altering the natural cycle of freshwater flow, but actually changing the entry point of this water into the marine environment. The environmental impact will therefore be completely different from that of other projects already carried out in Northern Quebec. It is highly important that we thoroughly study this unique case in order to improve our ability to predict the effects of harnessing rivers. This project is currently scheduled to begin by the end of the 1990s. It will be important to carry out at least one major sampling campaign during the summer before work begins, since our knowledge of this environment is currently limited to the winter period. Complete sampling of this region for two consecutive summers, including installation of current meters, would enable us to better understand the natural variability of this environment. These data combined with those to be collected after the construction work has been completed will allow us to assess the true impact of this hydroelectric development on the coastal environment of Hudson Bay. This research

avenue is therefore one of the priorities of the Physical Oceanography group in meeting future requirements for environmental impact analysis for hydroelectric projects. We are contemplating such projects as development of the Nottaway-Broadback-Rupert and Sainte-Marguerite complexes, as well as the final completion of the Grande Baleine complex.

Hudson Strait - The second research avenue selected for northern regions for the coming years involves the study of the Hudson Strait. At the Hudson Strait Workshop organized by the Department, in November 1989, it was pointed out that the two ends of this strait are the site of high biological productivity. Thus the eastern entry to the Hudson Strait has a large shrimp community that is fished commercially. This fishing activity generates significant income for the native communities of these regions. However, this zone of high productivity is relatively small in area. It therefore seems important to determine the physical mechanisms which have established this high-productivity zone in order to assess the inter-annual variability, and to predict variations in shrimp stocks and manage their exploitation efficiently.

The western entrance to the Hudson Strait is also the site of high primary productivity. Although a cruise to assess commercial fish stocks failed to turn up significant quantities, there are other signs that indicate the biological importance of the region. This confluence between the Strait, Hudson Bay, and Foxe Basin has a major bird community and forms a site which is home to a great many marine mammals. This entrance is very rich ecologically and merits a more thorough study. A multidisciplinary research project to study this region was proposed by the Physical Oceanography Division at the Symposium on the Gulf of St. Lawrence. The two entrances of the Strait are the sites of major biological processes related to specific physical phenomena such as intensive mixing zones generated by tidal currents. It would therefore be wise to plan an exhaustive study in the coming years.

The North Water project - The two avenues of research proposed for the coming years will be complemented by other more specific projects to respond to particular questions raised in the scientific community. Thus Division scientists hope to obtain the necessary financial resources to participate in 1993-94 in the North Water Project (NOW), which will study all the biological and physical mechanisms of the Davis Strait polynya. These regions are the site of considerable biological productivity, in addition to being potentially important zones for the formation and renewal of deep ocean waters. This project, which brings together scientists from across Canada and other countries, is part of the international program on the study of polynyas.

4.2 CHEMICAL OCEANOGRAPHY AND CONTAMINANTS DIVISION

In oceanography, chemistry plays two important roles. It provides the knowledge to make accurate chemical measurements which are essential to the study of the physical, biological and geological nature of the ocean, and it enables us to determine the composition, properties and chemical reactions of seawater, sediments, particles in suspension and marine organisms. One

of the main activities of the Chemical Oceanography and Contaminants Division (COCD) at the MLI is to study the distribution of chemical compounds, including contaminants, in the marine environment and the processes that control this distribution. Toxicology, or the study of the effects of exposing living beings to toxic chemicals, is another major sector of activities.

The Division is also interested in problems caused by contaminants. Climate change, marine ecology, the use of molecular markers, nutrient dynamics, and sediment geochemistry are also studied. To make the most effective use of our limited resources, most of the field work is carried out in the St. Lawrence system, mainly in the Gulf, the Estuary and certain tributaries. However, since the area under the Division's jurisdiction also includes the northern waters of Quebec, these waters will receive increasing attention in the future.

4.2.1 Carbon and nutrient cycles in the Gulf of St. Lawrence

An understanding of the carbon cycle is a determining factor in chemical oceanography, simply because the production and destruction of organic matter are the main processes that modify the composition of seawater. Gradients in the concentration of chemicals in the ocean are due mainly to the growth and breakdown of marine organisms. The problem of climate change is to a great extent linked to carbon movements in the ocean, which include the deposit, on the continental shelf, of carbon draining from the land and air, the exchange of carbon between the shelf and the high seas, carbon fixing on shelves and its burial in the sediments of continental borderlands. The inflow and recycling of nutrients, particularly nitrogen, which is necessary for the transformation of carbon into organic matter, are also closely linked to the carbon cycle. Determining the rates of production and mineralization of organic matter, as well as the rate at which organic carbon is withdrawn from the ocean cycle of that element by burial in the sediments of the continental margin, is a major problem.

The Division is participating in research on the carbon cycle through two projects on climate (JGOFS) which will continue until 1995 and will complement those carried out by the Biological Oceanography Division. One of these projects (COUPPB) is a multidisciplinary study of the physical, biological and chemical coupling of carbon and the way it is processed in the maritime estuary of the St. Lawrence. This work will be carried out in collaboration with researchers from the Physical Oceanography Division, the *Université du Québec à Rimouski* and the *INRS - Océanologie*. This project will study mesoscale vorticity, new and primary plankton production, particle flow towards the seafloor, benthic and pelagic coupling, and the distribution and activities of benthic macro- and micro-organisms.

The second JGOFS project is aimed at understanding the diagenesis of sediments and carbon and nutrient flux on the continental shelf, using the Magdalen Shelf area, in the southern part of the Gulf of St. Lawrence, as an area representative of all similar areas in temperate latitudes. The project involves observing the relevant geochemical and biological processes at selected sites and then conducting a laboratory study of the decomposition of organic matter, and the precipitation

and dissolving of inorganic carbon. The knowledge acquired during these studies will be used to construct a predictive model of diagenesis and the carbon cycle. This model should allow us to explore the potential consequences of natural and anthropogenic disturbances on the carbon cycle. The proposed research should also enable us to assess the possibility of carbon exchange between the Magdalen Shelf and the Laurentian Channel. This project will be carried out in collaboration with DFO researchers from the Scotia-Fundy, Newfoundland and Gulf Regions, as well as Dalhousie, McGill and Memorial Universities. Taking the perspective of the Gulf of St. Lawrence as an archetype of a marginal sea, we also propose to compare carbon dynamics in the Laurentian Channel and on the Magdalen Shelf with that of similar systems such as the Norwegian Channel and the southern part of the North Sea. This will allow us to better assess the effects of human activity on the St. Lawrence.

4.2.2 Chemistry of trace metals and nutrients

We have a fairly good idea of the overall distribution of trace metals and nutrients in the water column in the Gulf of St. Lawrence, as well as of metal deposit by the river in this environment. We know that trace metals are sufficiently mobile, that they are not for the most part trapped in the Gulf but exported to the open sea. We know a little about the distribution of metals and nutrients in sediments, as well as the chemical reactions and physical processes of transport governing this distribution. But there are many things we do not know about the temporal and spatial variations in the distribution of trace metals, even though it seems clear that these variations are quite significant.

Trace metals are closely linked to the activity of living organisms and the transformation of certain metals parallels that of nutrients. We do not know, however, whether these metals are directly involved in the carbon cycle or if there are other reasons for this parallel. Cadmium is a typical example of a metal whose cycle is similar to that of carbon. It is extracted from the surface layer of seawater. It is possible that this extraction is done by living organisms, but we do not know in what way. The extracted cadmium is transported away from the surface layer by particle sedimentation. It is redissolved in the water column and in sediments when these particles are destroyed. Although our present knowledge enables us to follow the path of cadmium in the marine environment, we still do not always understand the mechanisms by which cadmium is extracted from seawater in the surface layer and redissolved in the intermediate and deep layers as well as in sediments.

Contrary to cadmium, the fate of certain other trace metals is not directly governed by living organisms but depends on changes in chemical properties in the environment, which are caused by organisms. Manganese is a metal that is particularly sensitive to chemical changes in its environment when microbial activity has eliminated the oxygen and created a reductive environment. The progression of manganese in an aquatic environment is now qualitatively well known, and we are beginning to acquire information on the kinetics of the chemical reactions involved in this process.

Since the progression and evolution of trace metals are closely linked to biological activity and the carbon cycle, metals and carbon must be studied at the same time. For both these studies, we will be asking the same questions. Where and when are trace metals extracted from seawater? What are the mechanisms and kinetics involved? Where and when are these metals again released into solution and by what reactions and kinetics?

The Division has acquired considerable expertise and an international reputation for its work on sediment-water interactions. Projects on the chemistry of trace metals will further improve this expertise. Thus, the Division will pursue its studies on the distribution and diagenesis of metals in the sediments of the Laurentian Channel. In order to obtain access to highly specialized and costly apparatus, we will be collaborating with researchers from the Pacific Region (DFO) and the *Institut français de recherche pour l'exploitation de la mer* (IFREMER) in France. This collaboration will also enable us to generate a broader database to better understand the phenomenon studied. At the same time, we will be taking inventory of metal contaminants in the sediments found near the head of the Laurentian Channel to verify the hypothesis that these sediments form the main deposit area for contaminants transported by the St. Lawrence River. The role of the sediment-water interface in the nutrient and trace metal cycles will be researched in the St. Lawrence Estuary. This work will contribute to the development of a program to monitor environment quality in the St. Lawrence.

4.2.3 Marine organic chemistry

Marine organic chemistry includes various research fields that focus mainly on the chemical properties and reactions of organic molecules. It deals with the processes of recycling chemicals within the water column or between the water column and sediments, suspended matter, living organisms, as well as recycling in the oceans, the atmosphere and the continents. It is a multidisciplinary science that combines various aspects of geological, chemical and biological oceanography. It is distinguished from biochemistry in that it does not deal with the processes taking place inside living organisms. The links between marine organic chemistry and biological oceanography are strong since organic compounds are the "building blocks" of living organisms. Biological processes play a vital role in the distribution and modification of organic compounds. This distribution in turn is critical to the health of marine resources. Like geology, organic geochemistry deals with the transformation of organic compounds entering and escaping from sediments. These transformation and transport processes affect the long-term storage and availability of organic compounds. Physical oceanography is also extremely important for determining the transport and transformation of organic chemicals. Finally, the results of more traditional research (photolysis, hydrolysis, absorption, solubilization, volatilization, coagulation, polymerization) are also important in marine organic chemistry, since they serve to extrapolate data obtained in the laboratory in order to apply it to the natural environment.

Depending on their type, organic chemical compounds have distinct origins, properties and physical forms as well as vastly different effects on the marine ecosystem. As to their origin, they can be divided arbitrarily into natural products and anthropogenic chemicals.

4.2.3.1 Anthropogenic organic compounds

Among these compounds are all the chemicals created by man (the xenobiotics, such as pesticides, polychlorinated biphenyls and many halogenated organic products), as well as compounds occurring naturally, but whose concentrations in the marine environment have been modified by human activity (petroleum, sewer and industrial discharge and animal waste). Synthetic chemical compounds often follow the same processes and undergo the same reactions as natural substances. Environmental research on marine ecosystems has dealt mainly with toxic chemicals likely to persist in the environment, that is, products that are relatively stable over years or decades, are hydrophobic and can bioconcentrate. Among these products are the polycyclic aromatic hydrocarbons (PAH), petroleum hydrocarbons, pesticides such as DDT and toxaphene, certain organo-metallic complexes such as the organic complexes of lead, freons, dry cleaning solvents and many other halogenated products like polychlorinated biphenyls and dioxins. With respect to anthropogenic organic compounds, the Division will pursue research on the subjects briefly outlined below.

Organic contaminant sources, processing and sinks in the marine environment - Particular emphasis will be placed on lipid-soluble contaminants. Field work and laboratory experiments will be carried out to study the mechanisms and reaction speed of major processes such as the breakdown of contaminants. This research will deal with such matters as the distribution of contaminants and the reactions linked to their division between the liquid phase, the solid phase and the atmosphere. We will be asking a certain number of specific questions regarding stable organic compounds: What governs the division of hydrophobic organic compounds between the seawater solution and living organisms? What are the mechanisms and kinetics of the absorption of compounds from a solution? Is this phenomenon reversible? How do PCBs arrive at the top of the food chain? How does the atmospheric transport of hydrophobic anthropogenic organic compounds out of the Gulf compare to transport of these compounds by particles in suspension from the river? Is it possible to make a distinction between these two modes of transport in the case of the main pyrogenous PAHs? Can we establish a relation between the distribution of certain anthropogenic organic products in the recent sediments of the Gulf and the circulation pattern of waters or air masses? What are the major chemical properties governing the sharing of organo-metallic compounds between particles and the solution?

Environment-related monitoring of major organic chemicals at the local and global levels - We are particularly interested in long-term changes. The study of chronic pollution from ongoing sources is often postponed to give priority to acute pollution problems of immediate importance. These two types of study are necessary to ensure that marine habitats are preserved. Use of the word "monitoring" implies that sampling must be carried out regularly, even if all

chemical analyses are not necessarily done immediately. Fairly rapid analysis of general chemical characteristics should be complemented by a smaller number of more thorough studies on potential and newly identified pollutants. This work is part of the Division's overall effort to set up a significant environmental monitoring program.

Use of tracers to determine the scope of environmental contamination - The validation and quantification of existing tracers (coprostanol for sewage water, stable isotopic ratios for oil and acid rain pollution), and research on new tracers are important for the future of environmental research.

4.2.3.2 Organic compounds of natural origin

Among the natural products are the biomonomers such as sugars, amino acids, fatty acids, alcohols, ketones, aldehydes, sterols, terpenoids, hydrocarbons, phenols, quinones, aromatic acids, purines, pyrimidines and pigments; the biopolymers like carbohydrates, proteins, fats, lignin and nucleic acids; and the geopolymers like polymerized fats, resins and humic and fulvic acids. Monomers have been studied more extensively. Certain chemical compounds (sometimes known as "chemical fossils" or "biomarkers") can be used as tracers and indicators of environmental changes that occurred recently or in another geological era. For example, freons have been used to study the movement of water masses and ocean mixing. Many xenobiotics have also been used to measure sediment transport and mixing rates. These fields are developing rapidly through the introduction of new analytical methods in organic chemistry. For example, certain species of organisms synthesize unique, stable organic molecules whose presence in the environment unequivocally signals that of these organisms. We can sometimes establish a relation between environmental factors such as temperature and the compounds that are synthesized. In a recent study, attention was drawn to the fact that the fat composition of certain fish and marine mammals is determined genetically and might serve to identify and distinguish between populations or stocks of these animals. Research in the area of chemical communication indicates the possible existence of a link between the presence of trace chemicals and the movements of anadromous fish stocks.

The search for and use of natural organic compounds as tracers will be significant activities for the Division over the next five years. Recruiting new personnel and developing new analysis techniques will allow us to extend our field of research to include the important group of water-soluble organic compounds, among which are the natural toxins.

4.2.4 Biochemistry, molecular biology and marine microbiology

The processes that control the production and use of organic compounds and gases, and those that govern pH and oxidize and reduce minerals are, in turn, governed by the biochemistry and molecular biology of marine organisms. Marine biochemistry, molecular biology and micro-

biology are relatively new fields of study for the Chemical Oceanography and Contaminants Division, as this division has had specialists in these fields for only a short time. However, these specialties are becoming increasingly important within the Division because of their relevance and the fact that they are linked to other COCD activities.

CO_2 production in seawater: study of the enzyme reactions on which it depends - The questions currently being posed about the world carbon cycle, the greenhouse effect, climate change, the rise in the sea level and the accumulation of CO_2 in the atmosphere show how necessary it is to understand time and space variations in the CO_2 production rate in seawater. Not only is little known about this rate, but also there is no practical means of measuring it. Most of the CO_2 produced *in situ* in the water column in the ocean is produced biologically and nothing is known about the biochemistry of this process in marine organisms. To explain the production of CO_2, the probable but as yet unproven hypothesis has been advanced that the three enzymes of the tricarboxylic acid cycle, pyruvate-dehydrogenase (PDH), isocitrate dehydrogenase (IDH) and alpha-ketoglutarate-dehydrogenase (a-kDH), control the release of CO_2 from organisms into seawater. The Division will be doing research to verify this hypothesis.

The role of new protein synthesis in the regulation of enzyme activity in marine organisms - From an oceanographic standpoint, the important processes of production and consumption of oxygen and carbon dioxide, nitrate reduction, production and oxidation of ammonium, production of sulfur and several other processes depend on the enzyme reactions in marine organisms. To understand, measure and predict these processes, we must know the kinetics that control the reactions they bring about. But we can only acquire this knowledge by studying the relations between enzyme reactions and the physiological processes that depend on them, enzyme kinetics and molecular biology linked to genetic regulation of the synthesis, and deterioration of enzymes. Although we are starting to recognize the importance of molecular biology, only the Hopkins Marine Laboratory in the U.S. has undertaken a research program in this area. At the MLI, we are currently working with the Hopkins group to study the problem of regulating nitrate-reductase in the reduction of nitrates in algae and a pilot project has been completed. The MLI is now considering the use of modern molecular biology and biochemistry techniques, insofar as they have applications in oceanography. To apply the advances already made at the Hopkins Marine Station and to take advantage of the expertise of a new MLI researcher, this research will initially concentrate on understanding nitratereductase enzyme regulation.

Many reactions catalysed by enzymes are due to bacteria. Research will therefore be undertaken to determine the rate of bacterial activity and the production rate of the bacterial biomass in the St. Lawrence system, in order to identify which factors serve to make these rates more constant. In particular, we will be studying the relation between the flow of particles to sediments and bacterial activity in the benthic boundary layer. Other related research will deal with the role of bacteria in the natural degradation of oil and the importance of benthic bacteria in areas where there is oil seepage, with regard to the energy needs of benthic organisms.

4.2.5 Toxicology

Chemical contamination of aquatic ecosystems is a relatively new question for the DFO. Initially, the main concern was for spot releases of large volumes of waste, particularly in ports on fresh water or salt water. In the case of the Gulf of St. Lawrence, significant dilution with ocean waters appeared to provide ample protection. It thus appeared that, for the majority of commercial fisheries, chemical contamination was not a matter of concern and was not a factor to be considered in fisheries management or scientific activities. However, due to improved analytical techniques and the fact that we now know more about the sometimes subtle effects of environmental contamination on human health, attitudes and perceptions are currently changing at the DFO. We now know that many chemicals that are toxic for humans are persistent, transported over long distances and found concentrated in sediments and aquatic organisms. Incidents linked to fish that cannot be eaten without risk are increasing, even in Arctic regions far from all effluent discharge points. Marine mammals like the beluga are much more threatened than humans because of their position at the top of the food chain. Since their diet is mainly composed of fish, belugas, which live a long time and have large reserves of fat, become, in a way, storehouses for lipid-soluble toxic chemicals.

Despite the many problems of chemical contamination, we see very few effects due to chemicals in fish, either direct toxic effects or effects on the food chain. Most of the effects observed are the result of acute problems, including, for example, the problem of fish mortality or the absence of fish near industrial waste discharge sites. Knowledge of the chronic effects on behaviour, growth rates, reproduction or mortality is normally acquired from laboratory studies.

Over the past ten years, there has been an increasing number of alarming reports describing the possible effects of toxic chemicals. In fish, cancers, deformities and high-incidence diseases appear to be more common in the waters located near urban and industrial centres. Studies on fish caught near the effluents of specific industries, such as those of pulp and paper plants, have enabled us to describe the symptoms of exposure to chemicals: the symptoms of stress, toxicity, physiological dysfunction; problems with the reproductive system; a high incidence of disease; and changes to the population, structure and productivity of fish communities. These symptoms can be detected even at great distances from spot emissions (as much as 100 km or more). In fact, they are detectable wherever there is chemical contamination nearby.

Although these results concur with those of laboratory studies and the distribution of effects coincides with that of pollution, it is difficult to establish concrete causal effects, particularly for specific chemical constituents. It is also difficult to see how fish or fish populations will react to specific chemicals or effluents, since detailed studies have been made of the effects of only a small number of these products. Thus, the fisheries resources threatened by chemical pollution, the seriousness of potential losses, and the methods or approaches that would allow us to recognize or measure the chemical risks, all remain relatively unknown.

4.2.5.1 Toxicology of the St. Lawrence system

The St. Lawrence River and a great many of its tributaries in southern Quebec (in the Montreal area) are very contaminated, according to the warnings issued on the consumption of fish caught by sports fishermen. As well, the St. Lawrence acts as a conduit for the transport of contaminants from the Great Lakes. There have been reports of high incidence of deformity and disease in fish, the disappearance of some species and a decline in the volume of catches. Although the river is one of the most contaminated in Canada, the role of the toxicity of chemicals in the deterioration of the environment is not clear, because massive changes in the physical habitat have also destroyed the reproductive and nursery areas of the fish. The Division will pursue the study of the effects on fish due to effluents from a pulp mill using the chlorine bleaching process. This will be done in co-operation with researchers from Environment Canada and the *Université Laval* as part of a national effort aimed at thoroughly characterizing the environmental effects of these mills. This will involve documenting the morphological, biochemical and hematological changes occurring in fish as the result of exposure to chemicals in pulp mill waste, documenting the consequences of these changes and attempting to establish the causes on the molecular scale.

The St. Lawrence flows into the Gulf of St. Lawrence. The inflow of chemicals into the Gulf is considerable, but due to the high level of dilution and the complexity of hydrological and biogeochemical cycles, concentrations appear low compared to those found in systems like that of the Great Lakes. Nevertheless, this inflow results in high concentrations of toxic chemicals in the tissues of belugas. The toxicity of these products may be a major factor in preventing the growth of beluga populations.

To assist in finding the sources of contamination of belugas and to explain the toxicity of contaminants in this species, the Division will carry out a major study on eels and their role in the contamination of belugas under the St. Lawrence Action Plan. The toxicity of chemicals does not seem to affect the survival and migration of eel. Many cases of death have been associated with migration and these are perhaps due to the combined stress of migration, adapting to salt water and the acute toxicity of chemicals encountered during migration. Eels in southern Quebec and in the Great Lakes are very contaminated by persistent organic compounds. The eels of Lake Ontario can be recognized by their high mirex content. The question of whether contamination interferes with migration, survival and reproduction during annual spawning in the Sargasso Sea is as yet unanswered. This migration may also explain the presence of chlorinated organic compounds found in high concentrations in belugas, assuming that they eat eels.

The Saguenay, one of the rare fjords in Eastern Canada and Quebec's first marine park, is also polluted. Industrial wastes discharged at the head of the fjord and its tributaries have been found in the sediments. The mercury contamination has led to a ban on commercial fishing for shrimp and other fish. Little is known about the relative mobility of contaminants in the Saguenay or their contribution to the contamination of belugas. For this reason, the Division has decided to

participate in a large-scale multidisciplinary project to study contaminants and toxicity in the fish and benthic invertebrates in the St. Lawrence Estuary and the Saguenay Fjord.

The management of fishing in contaminated ecosystems calls for a thorough understanding of the sources, distribution, transport, metabolism and effects of chemicals in aquatic ecosystems. The Chemical Oceanography and Contaminants Division will be carrying out research on the following general topics over the next five years:

- Mechanisms that govern the cycle of chemicals in aquatic environments and the accumulation of these products in the biota;

- Mechanisms that explain the toxicity of chemicals in the biota;

- Consequences of this toxicity, i.e. its effects on fish populations and on fishing;

- Interactions between these mechanisms and specific environmental factors such as the physical and chemical characteristics of an ecosystem, and the specific history of the biota therein;

- Dose-response relations;

- Definition of the nature, causes and consequences of specific chemical pollution problems in Quebec; and

- Appropriate measures to deal with problems of chemical pollution.

4.2.6 Paleoceanography

Biological productivity and the absence or presence of major fish species in the Gulf of St. Lawrence are sensitive indications of environmental conditions. These conditions have evolved and will continue to evolve. It is in the sediments that we find indications of the relation between the environment and the biology of the Gulf, since it is there that the chemical and biological indicators of the conditions that prevailed at the time of deposit are preserved. The sensitivity of the system to anthropogenic and climatological effects could be assessed if we could set up well-documented records of how these indicators have changed in the past. In turn, this information could be useful to predict changes that will occur in the future.

The time scales of anthropogenic changes (between 10 and 100 years) and climate changes (over 100 years) are very different. But the close coupling that currently exists between anthropogenic and climatic effects on phenomena such as the increase in concentrations of CO_2, thinning of the ozone layer in the stratosphere and the atmosphere-ocean cycle of methane has modified the two time scales. To understand the dynamic aspects of this coupling, we must go back into the past to reconstruct the respective influences on these phenomena of biogeochemical parameters.

Many questions can be dealt with in paleoceanographic studies: To what extent have anthropogenic discharges modified the biogeochemical regime of the Gulf and to what time scale do these changes correspond? What were the main climate changes and to what extent has the present temperate environment of the Gulf been subject to major Arctic influences? What effect has this had on its productivity? How has the hydrology of the St. Lawrence River varied over intermediate time scales (100 -1000 years)? Do these changes tell us anything about the temperature and precipitation at that time?

There is a wide variety of sedimentological parameters needed to answer these questions. Among the anthropogenic markers are inorganic and organic chemicals (Hg, Pb, Cd, PAHs, PCBs, etc.), radionuclides (Cs-137, Pu-239, 240, etc.) and acid rain indicators (microfossils, etc.). Among the climatological markers are organic matter (lignin, stable isotopes, relative proportions of C, H, N and S), palynological and paleontological indicators such as microfossils and relations between isotopes of oxygen, radionuclides like C-14, hydrological tracers, sediment texture characteristics (grain size, mineralogy) and seismic signals (e.g. discordance, surface erosion).

The Division will not be undertaking a complete paleoceanography research program but will apply paleoceanography techniques to study the contaminant concentrations, flux and trends in order to determine seabed concentrations of contaminants.

4.2.7 Mathematical modelling

Mathematical models can be used in many ways. A correctly formulated model may be used to discern information which would otherwise be difficult to measure such as that related to fluxes. Models can forecast the evolution of a system over time. Models can also determine where and when certain processes dominate in a series of competitive processes. Sensitivity studies can indicate exactly what information is pertinent, what parameters should be measured and to what extent the parametering plan is valid.

Modelling should be considered an essential component of the activities of the Division, since it can both supply basic scientific information and serve as an environmental management and analysis tool.

Within the context of the research themes we have defined, modelling should indeed be considered an essential constituent if we hope to arrive at a quantitative explanation of the geochemistry of the Gulf of St. Lawrence and predict the effects of anthropogenic disturbances. In particular, in studying the carbon cycle, we will have to calculate carbon and nutrient flux based on profiles of these substances in the interstitial water of sediments, if these fluxes cannot be measured directly. We need a diagenetic model into which we can incorporate a realistic kinetics for the deterioration of organic matter and an appropriate description of transport processes in sediments (diffusion, bioturbation, irrigation, currents moved by pressure and sediment transport). If the data indicate that the site of primary regeneration is not in the production zones, we

must have a model to study the dynamics and time scales of transport between production and remineralization zones. We could start with a simple box-type model, coupled to a benthic (diagenetic) model, but eventually we will need to determine the link between three-dimensional circulation and transport models and a spatially varying benthic model.

The various transformations identified through the study of trace metals and organic compounds should be compared using mathematical simulation. This will bring out the most important components in these equations which in turn will allow us to calculate the fluxes that feed the system. Such a model would also enable us to predict the evolution of disturbances caused by contaminants.

The Division's experience in mathematical modelling of water-sediment interaction phenomena will be used to build models simulating these and related phenomena which will be used together with *in situ* and laboratory diagenesis tests.

CANADIAN HYDROGRAPHIC SERVICE BRANCH

Nationally, the Canadian Hydrographic Service (CHS) produces and updates the complete range of official nautical charts and documents that are indispensable to safe navigation in Canadian waters. These navigational tools include nautical charts, sailing directions, current and tide tables, and current atlases.

The Canadian Hydrographic Service Branch (CHSB), also known as the Canadian Hydrographic Service - Quebec Region, is responsible for the marine cartography of one of the busiest navigation areas in the world. This area comprises the St. Lawrence River from Beauharnois, the St. Lawrence Estuary and the part of the Gulf of St. Lawrence that touches the coasts of Quebec, the navigable waters of the Richelieu and des Prairies Rivers and part of the Ottawa River, as well as lakes Memphremagog and Saint-Jean. Northern Quebec and the Canadian Arctic are currently excluded from this area due to a lack of regional resources.

The Canadian Hydrographic Service Branch includes three divisions: Hydrographic Data Acquisition; Marine Geomatics; and Nautical Publications (FIGURE 1 and FIGURE 7). Its target clientele is mainly commercial navigation, National Defence, ferry services, pleasure craft operators, fishermen, scientists and professionals working in the marine and ocean sciences field. The Branch's production is aimed at maritime transport safety, economic development linked to the maritime sector, the supply of professional and technical services to the Canadian Coast Guard (CCG) and to rescue teams in the event of environmental catastrophies or marine disasters.

The Branch currently produces and updates approximately 75 nautical charts. Nearly 50% of these charts are based on data from before 1960 (the majority of which dates back to pre-1940) and 25% are based on data collected before 1980. Only 25% of all the nautical charts covering the Quebec Region's territory are considered recent and satisfy current national and international standards.

In order to complete its mandate, the CHSB will maintain its inter-regional co-operation and projects. It will, among other things, carry out personnel exchanges, multidisciplinary projects, database development and ship exchanges with the Scotia-Fundy Region. The Branch will also intensify the exchange of personnel and equipment loans with Central & Arctic and Pacific Regions in order to achieve the optimum use of the resources currently available in Canada.

FISCAL YEAR 1992-93
Canadian Hydrographic Service 42.0 P/Y (Base)

APRIL 1992

DEPARTMENT OF FISHERIES AND OCEANS
REGIONAL SCIENCE BRANCH
QUEBEC REGION

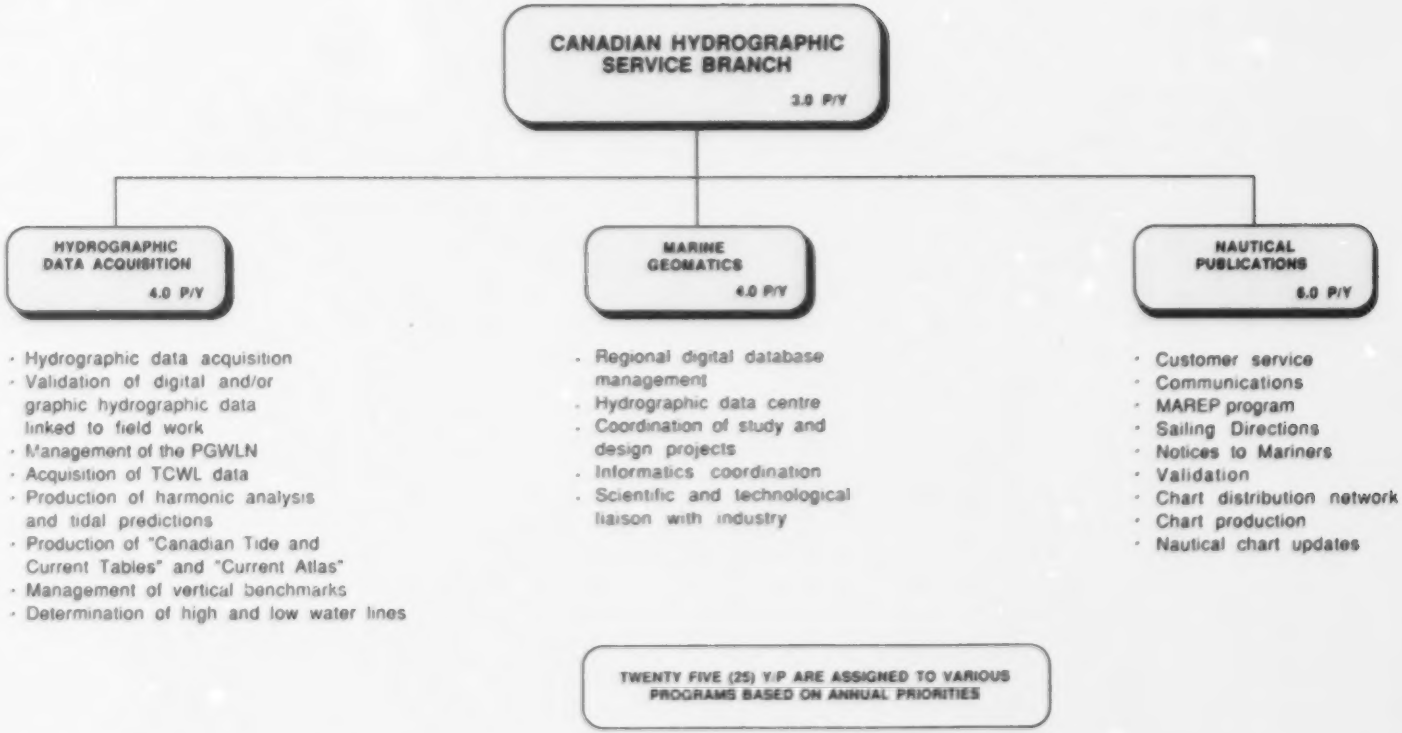
CANADIAN HYDROGRAPHIC SERVICE BRANCH
3.0 P/Y
HYDROGRAPHIC DATA ACQUISITION
4.0 P/Y
- Hydrographic data acquisition
- Validation of digital and/or graphic hydrographic data linked to field work
- Management of the PGWLN
- Acquisition of TCWL data
- Production of harmonic analysis and tidal predictions
- Production of "Canadian Tide and Current Tables" and "Current Atlas"
- Management of vertical benchmarks
- Determination of high and low water lines
MARINE GEOMATICS
4.0 P/Y
- Regional digital database management
- Hydrographic data centre
- Coordination of study and design projects
- Informatics coordination
- Scientific and technological liaison with industry
NAUTICAL PUBLICATIONS
6.0 P/Y
- Customer service
- Communications
- MAREP program
- Sailing Directions
- Notices to Mariners
- Validation
- Chart distribution network
- Chart production
- Nautical chart updates
TWENTY FIVE (25) Y/P ARE ASSIGNED TO VARIOUS PROGRAMS BASED ON ANNUAL PRIORITIES

FIGURE 7 : Fields and areas of activity of the Canadian Hydrographic Service Branch and allocation of personnel.

5.1 Service to clients

The Canadian government's focus on increasing and improving service to the Canadian public has not been forgotten in the long-term plan of the Canadian Hydrographic Service Branch. On the contrary, this concern is essential to the justification of developing the priorities in this plan.

Various steps have been taken by the Branch in recent years to provide quality service to the public:

- **Fulfilling its legal mandate** - The CHSB works to maintain its technical and professional expertise in producing nautical charts and related documents that ensure safe navigation in Canadian waters.

- **Modelling operating priorities** - The CHSB will model a series of time, physical, economic and political parameters in order to give priority to projects based on the resources available to meet the needs of target clienteles.

- **User consultation** - The CHSB ensures that all of its new projects and products are presented to the target clientele to meet the needs and determine the future requirements of its clientele.

- **Co-operation with partners** - In light of the decrease in resources available to fulfil its legal mandate, the CHSB is doing its best to form new partnerships in order to combine interests. This will allow it to carry out projects to which several parties can contribute and from which they can derive mutual benefit. Strategic alliances already established with the private sector and government institutions are being called on more frequently in order to achieve optimum use of allocated resources.

- **Product dissemination, distribution and promotion** - The CHSB manages a complete network of authorized dealers for the distribution and dissemination of its official products. As part of the Scientific Information and Liaison Strategy, and with the support of the Regional Communications Branch, it has implemented a plan to promote its products using a marketing approach suggested by a consulting firm. This plan is aimed at grouping together all CHSB products under a single commercial logo rather than under an arrangement which is unfamiliar to much of the target clientele. This logo is called: "CO-PILOT, the full range of nautical charts and documents".

Service to clients will remain a basic priority for the Branch over the next five years. The pressing need for digital hydrographic data is having an ever-increasing impact on its activities. We can already confirm the growing interest of various clients in the use of high-performance technologies like Geographic Information Systems (GIS). This new need in marine geomatics is evidenced by the frequent, repeated requests for information received by the CHSB. This trend will

significantly influence priorities, operating methods and resource allocations for setting up a hydrographic infostructure in the future.

The race by the private sector to derive profits from marine activities, rapid technological and informatic developments in the field of navigation, as well as the increase in the number of pleasure boats are factors that will compel the CHSB to readjust its production in order to meet the more specific needs of its clientele. A digital model to establish priorities in hydrographic research will be set up in conjunction with an improved user consultation process in order to determine the needs of mariners and establish action plans accordingly. The Branch will promote and encourage the ratification of tentative agreements with partners, in order to rationalize its activities by operating with a minimum of available resources and within a difficult economic and political context.

5.2 Hydrographic infostructure

Hydrographic infostructure is the digital information distributed through computer media and used as the basis of an overall infrastructure to manage and disseminate hydrographic data. Setting up such an infostructure within the Branch will require a complete restructuring of its operating procedures in terms of its traditional functions. The current organizational structure and the investment already made in training multidisciplinary employees will enable us to easily direct CHSB activities towards the management, updating and gradual dissemination of digital data in order to respond to the new and ever-growing needs of our clientele. We only have to think of the electronic nautical charts available on Canadian and international markets which will not be able to be backed up by digitally "pure, validated and current" hydrographic data. In the same vein, strong economic pressure is coming from the Canada Ports Corporation, the main ports authorities, the Canadian Coast Guard and from users of the CHSB in general to modernize and improve access to a digital Permanent Gauge Water Level Network (PGWLN). The urgent needs of these organizations leave the CHSB no choice other than to immediately and actively start reallocating its resources to the validation, management, updating and dissemination of digital hydrographic data.

It is clear that internal resources cannot be reallocated without affecting traditional operations, i.e. data acquisition and the production of nautical charts and documents. The CHSB must first gradually limit its "hydrographic data acquisition" component to the actual needs of processing and limit the "development" aspect to applications that respond only to client requirements. Data will increasingly be processed using automated means so that digital data can become a basic product of the CHSB in the short or medium term. At the national level, the Canadian Hydrographic Service has already adopted guidelines for the management of digital hydrographic data. In the regions, we will maintain and further develop this national orientation in view of the fundamental importance of a common structure in the management of digital hydrographic data.

The principal mandate of the CHSB, which is to produce and update the full range of official nautical charts and documents in order to ensure navigational safety in the waters under its jurisdiction, will be implemented as follows for the period 1992 to 1996:

- The Hydrographic Data Acquisition Division will give priority to bathymetric surveys in the Montreal, Mid and Lower Quebec North Shore regions; to the modernization, management and operation of the digital Permanent Gauge Water Level Network; and to the setting up of a digital model for predicting tides and currents (TABLE 2).

- The Marine Geomatics Division will be responsible for implementing the Hydrographic Information Network (HIN), testing commercial "packages" and managing and validating digital hydrographic data. The transfer of technology and the establishment of strategic links with the private and academic sectors in ocean sciences will be increased and promoted. This will be done by coordinating the introduction and development of new technologies in order to enhance the level and quality of production, while keeping the use of CHSB resources to a minimum (TABLE 2).

- The activities of the Nautical Publications Division will include: processing hydrographic data to produce nautical charts and documents; producing five new A0 charts, four new editions of charts, three new A2 charts, three diagrams, and one descriptive booklet for Sailing Directions; producing ten to fifteen chart insets per year as needed; and updating existing charts. Other priority activities will include managing the commercial distribution network for CHSB products; implementing the Scientific Information and Liaison Strategy with clients; developing the "CO-PILOT" logo and marketing; and public and interdepartmental consultation (TABLE 2 and FIGURE 8).

The current economic and political situation, as well as the situation that can be anticipated for the coming decade in maritime affairs, will favour communication, co-operation and partnership with those involved in this field at departmental and interdepartmental levels, and with Crown corporations and government agencies, universities, provincial government bodies and even the private sector. Opportunities that currently exist (the St. Lawrence Action Plan, the hydroelectric development in Northern Quebec, the Green Plan for Canada, the recommendations of the Brander-Smith Report) and others to come, will make it important to be able to offer hydrographic coverage using digital geographic data as quickly as possible.

The CHSB must ensure that hydrographic mapping is known and recognized as the "basic infrastructure" of all developments in the navigable waters of Quebec, whether they be economic, social, scientific or in the area of new transportation infrastructures. This recognition should be in the form of partnerships and mutual contribution in order to accelerate the implementation of the Branch hydrographic infostructure. This marine geomatics environment will become a necessity for all current clients, as well as the many future customers, and will enable them to adequately use their Geographic Information System and electronic charts.

TABLE 2 : Project planning at the Canadian Hydrographic Service Branch, 1992-1996.

	1992	1993	1994	1995	1996
DATA ACQUISITION	Contrecoeur to Montréal Revisory surveys	Lac Saint-Louis Photogrammetry Revisory surveys Mid-North Shore Lac Saint Louis	East of Port of Québec Revisory surveys Mid and Lower North Shore Mingan Lac Saint-Louis	East du Port de Québec Revisory surveys Mid and Lower North Shore	Saguenay Revisory surveys
MARINE GEOMATICS	Modernization of PGWLN/TCWL, HIN Data management + HDC Dedicated computer systems ORACLE, GIS,CARIS, GPS,Remote sensing	HIN Data management + HDC Dedicated computer systems ORACLE, GIS,CARIS, GPS,Remote sensing	HIN Data management + HDC Dedicated computer systems ORACLE, GIS,CARIS, GPS,Remote sensing	HIN Data management + HDC Dedicated computer systems High-density telecommunication	HIN Data management + HDC Dedicated computer systems High-density telecommunication
NAUTICAL PUBLICATIONS	NC Blanc-Sablon (A2) NC Îles-de-la-Madeleine North (A0) 1 Descript. leaflet for Sail. Dir. 3 diagrams for Sail. Dir. Chart insets	NC Passage Saint-Augustin (A2) NC Lac Saint-Pierre (A0) NE Lac Saint-Pierre to Lavaltrie (A0) Chart insets	NC Port of Montréal (A0) NE Cap de la Tête aux Chiens to Cap aux Oies (A0) Chart insets	NC Riv.-au-Tonnerre to Pte Saint-Charles (A0) NC Mingan (A2) NE Port of Québec NE Gaspé Peninsula(A0) Chart insets	NC Îles-de-la-Madeleine (Small scale) NC Sorel to Varennes (A0) Chart insets

SEE APPENDIX 1 AND 2 FOR THE DEFINITION OF ABBREVIATIONS AND SYMBOLS

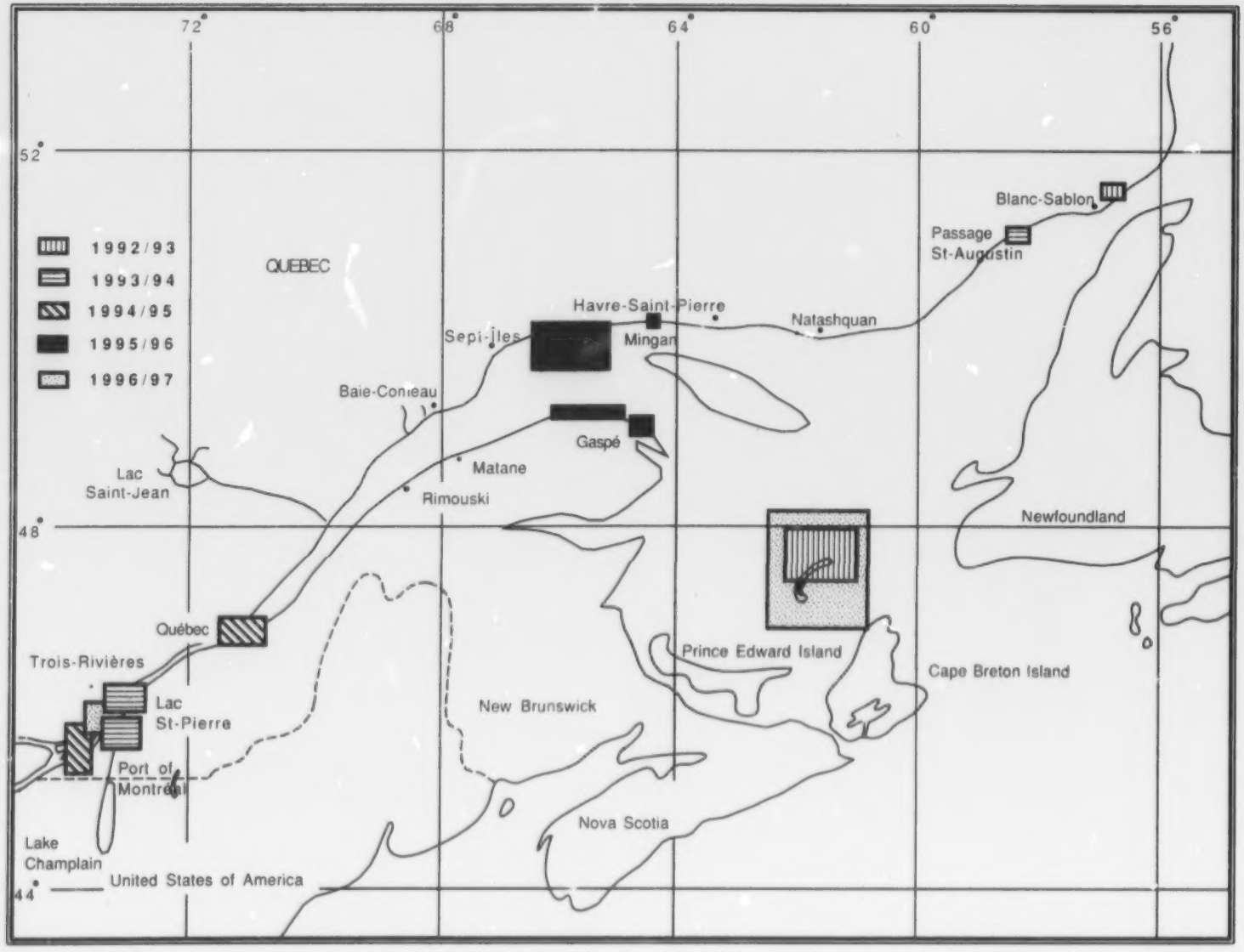

FIGURE 8 : Map production planned by the Canadian Hydrographic Service Branch, 1992-1996.

This hydrographic infostructure will gradually become the product that will shape the CHSB's future reputation, just as paper nautical charts and documents have done for the more than one hundred and seven years of hydrography in Canada!

APPENDIX 1

LIST OF ABBREVIATIONS

AFAP	Atlantic Fisheries Adjustment Program
A-kDH	Alpha-ketoglutarate - dehydrogenase
AMPD	Aquaculture, Marine Mammals and Parasitology Division
BOD	Biological Oceanography Division
BSB	Biological Sciences Branch
CAFSAC	Canadian Atlantic Fisheries Scientific Advisory Committee
CAPQ	Conseil de l'aquiculture et des pêches du Québec
CCG	Canadian Coast Guard
CHS	Canadian Hydrographic Service
CHSB	Canadian Hydrographic Service Branch
CNRS	Centre national de la recherche scientifique
COCD	Chemical Oceanography and Contaminants Division
COUPPB	Couplage entre les processus physiques et biogéochimiques
DDT	Dichloro-diphenyl-trichloro-ethane
DFO	Department of Fisheries and Oceans
DMS	Dimethyl-sulfur
DMSP	Dimethyl-sulphonium-proprionate
DNA	Desoxyribonucleic acid
EARP	Environmental Assessment and Review Process
FHD	Fish Habitat Division
FRD	Fisheries Research Division
GIROQ	Groupe interuniversitaire de recherches océanographiques du Québec
GIS	Geographic Information System

GPS	Global Positioning System
HDC	Hydrographic Data Centre
HIN	Hydrographic Information Network
ICES	International Council for Exploitation of the Sea
IDH	Isocitrate-dehydrogenase
IFREMER	Institut français de recherche pour l'exploitation de la mer
INRS	Institut national de la recherche scientifique
IREP	International Recruitment Experiment Program
JGOFS	Joint Global Ocean Flux Studies
LIDAR	Light Detection and Ranging
LRTAP	Long-Range Transport of Atmospheric Pollutants
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
MAREP	Marine Report
MENVIQ	Ministère de l'Environnement du Québec
MLI	Maurice Lamontagne Institute
NAFO	North Atlantic Fisheries Organization
NC	New Chart
NE	New Edition
NOW	North Water
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PCSB	Physical and Chemical Sciences Branch
PDH	Pyruvate-dehydrogenase
PGWLN	Permanent Gauge Water Level Network

POD	Physical Oceanography Division
QFFDP	Quebec Federal Fisheries Development Program
RADAR	Radio Detection and Ranging
RCB	Regional Communications Branch
REPERE	Recherche sur les pectinidés à des fins d'élevage et de repeuplement
RSBQ	Regional Science Branch - Quebec Region
RSB	Regional Science Branch
SCD	Scientific Computing Division
SLAP	St. Lawrence Action Plan
SLC	St. Lawrence Centre
TCWL	Tides, Currents and Water Levels
UQAR	Université du Québec à Rimouski
WOCE	World Ocean Circulation Experiment

APPENDIX 2

LIST OF SYMBOLS

AO	Nautical charts, 141 mm X 1189 mm
A2	Nautical charts, 420 mm X 594 mm
C	Carbon
°C	Degrees Celsius
CO_2	Carbon dioxide
Cs	Cesium
Cd	Cadmium
g/L	Grams per litre
H	Hydrogen
Hg	Mercury
km	Kilometre
m	Metre
mg/L	Milligrams per litre
mm	Millimetre
N	Nitrogen
Pb	Lead
ppm	Parts per million
Pu	Plutonium
S	Sulfur